VOLUME XXII NUMBER TWO

THE NATIONAL GEOGRAPHIC MAGAZINE

FEBRUARY, 1911

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With 48 Illustrations

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Illustrated

National Geographic Society Notes

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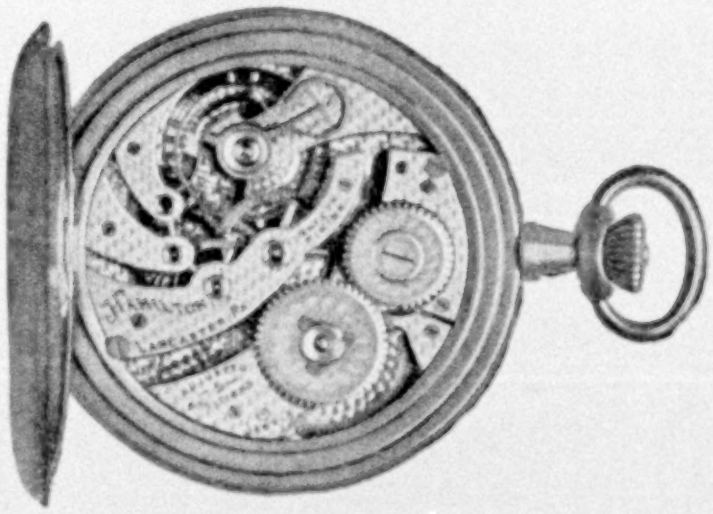

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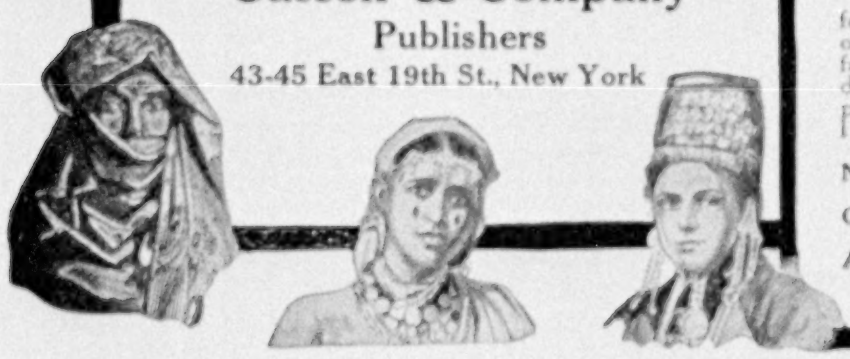

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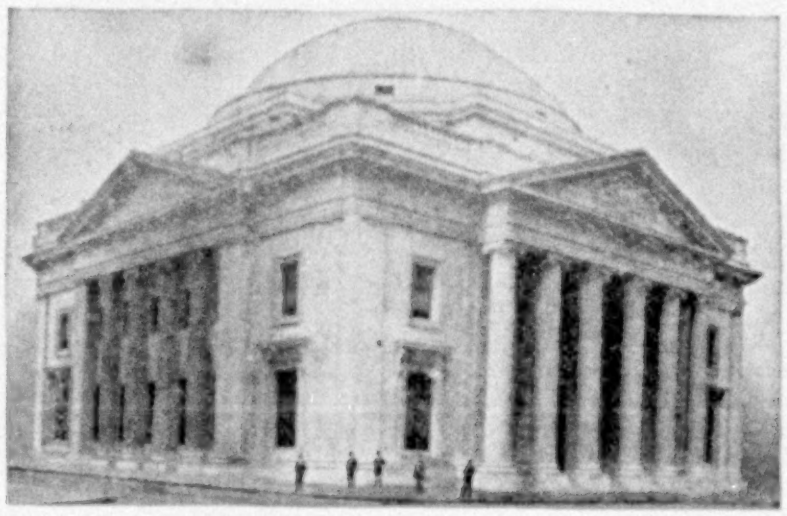

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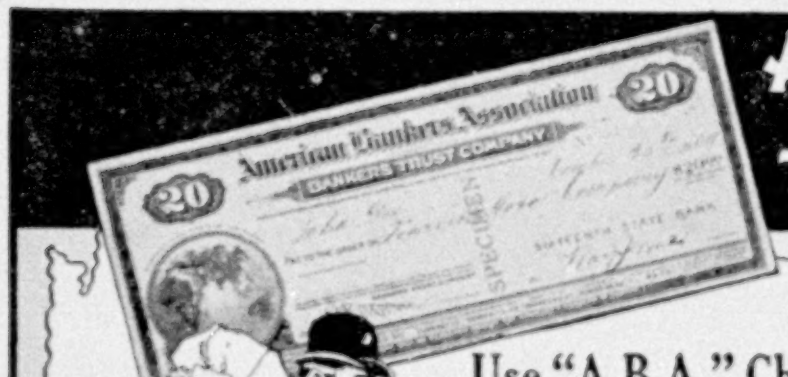

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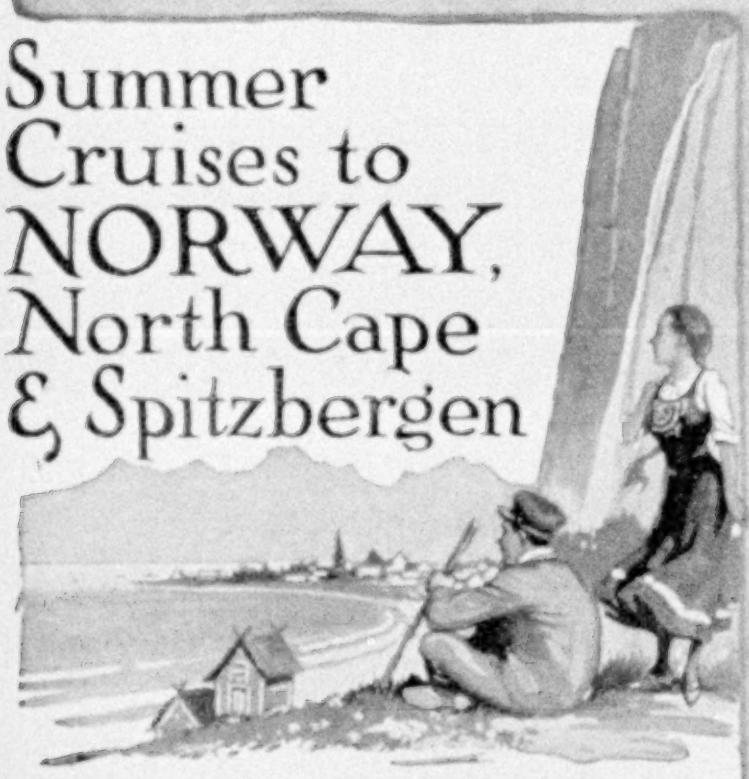

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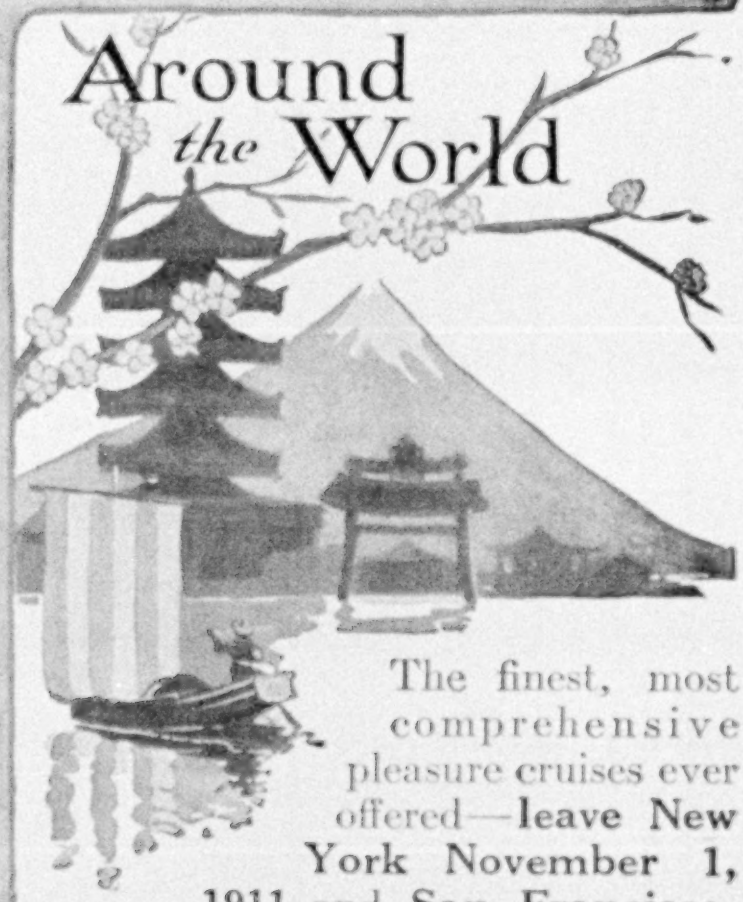

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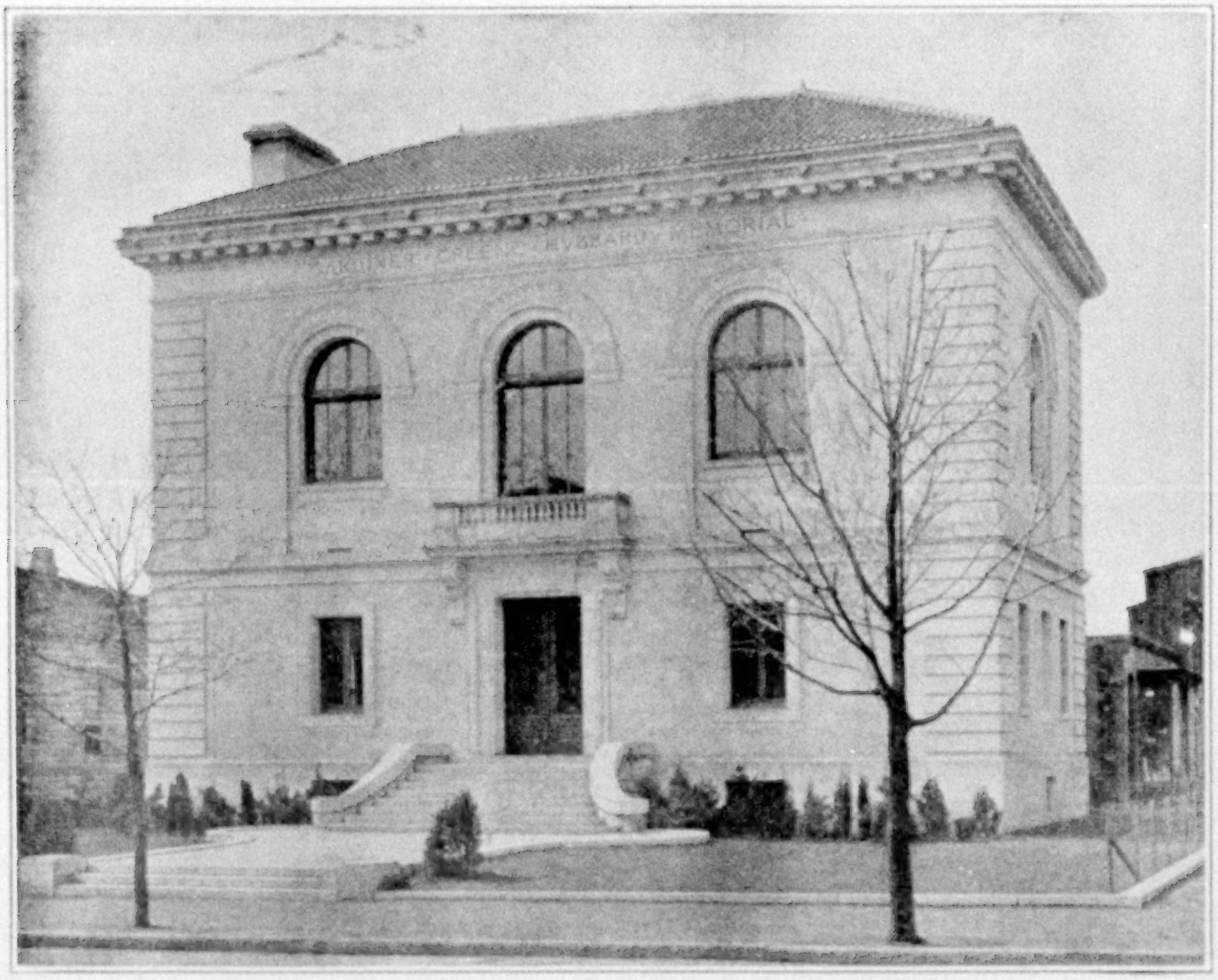

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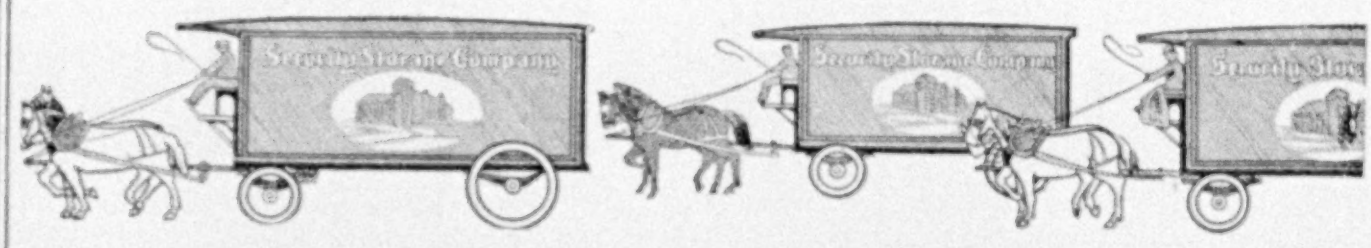

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VOL. XXII, No. 2 WASHINGTON FEBRUARY, 1911

THE NATIONAL GEOGRAPHIC MAGAZINE

THE SNAKE DANCE

BY MARION L. OLIVER

IT was after a hot day's march across the desert that I had my first glimpse of Oraibi, one of the pueblo towns of the Hopi Indians. It looked like some gigantic fortress, looming in the distance above miles and miles of desert sand.

As we rode nearer we saw that at the foot of the great rock on which the town was built were little patches of corn and a few peach trees, tiny gardens which looked parched and stunted in the hot sun of the desert. We pitched our camp at the foot of the mesa and spent the night waiting in great excitement for the morrow, when we were to see the greatest religious ceremony of the Hopis, the Snake Dance, which takes place only every two years, and for which we had come so far. The dance was to take place at the hostile village, "Ho-Ta-Vila," 7 miles beyond Oraibi. This village to many is more interesting than the other older towns, for there missionaries are not welcome, schools do not exist, clothes are not thought necessary, and the old faith of the Hopis is guarded and taught with care by the Antelope and Snake priests.

At last morning came, and at the first notes of the reveille I was up. My tent was open and even from my blankets I could see in the dim morning light the great wall of the mesa, several hundred feet high, with the Hopi village on top, frowning at the white men who had come to see the sacred ceremony of the Hopi nation. Although it was very early, I could hear from time to time songs and voices floating down on the chill morning air; evidently the village was wide awake. The time passed all too slowly, and breakfast and the regular camp routine seemed unending.

At last 11 o'clock came, and, mounting our horses, we started for what proved a most thrilling experience. We had to ride up a very hard trail over the mesa, through Oraibi, and on over the desert on the other side. The trail was filled with both Navahos and Hopis on little underfed Indian ponies, all on their way to see the "big medicine." Soon the hostile village, Ho-Ta-Vila, was reached. Everywhere there was a feeling of intense excitement, and already the roofs of the adobe houses surrounding the tiny plaza were being covered with gaily dressed squaws and little naked children, looking like tiny mahogany cupids.

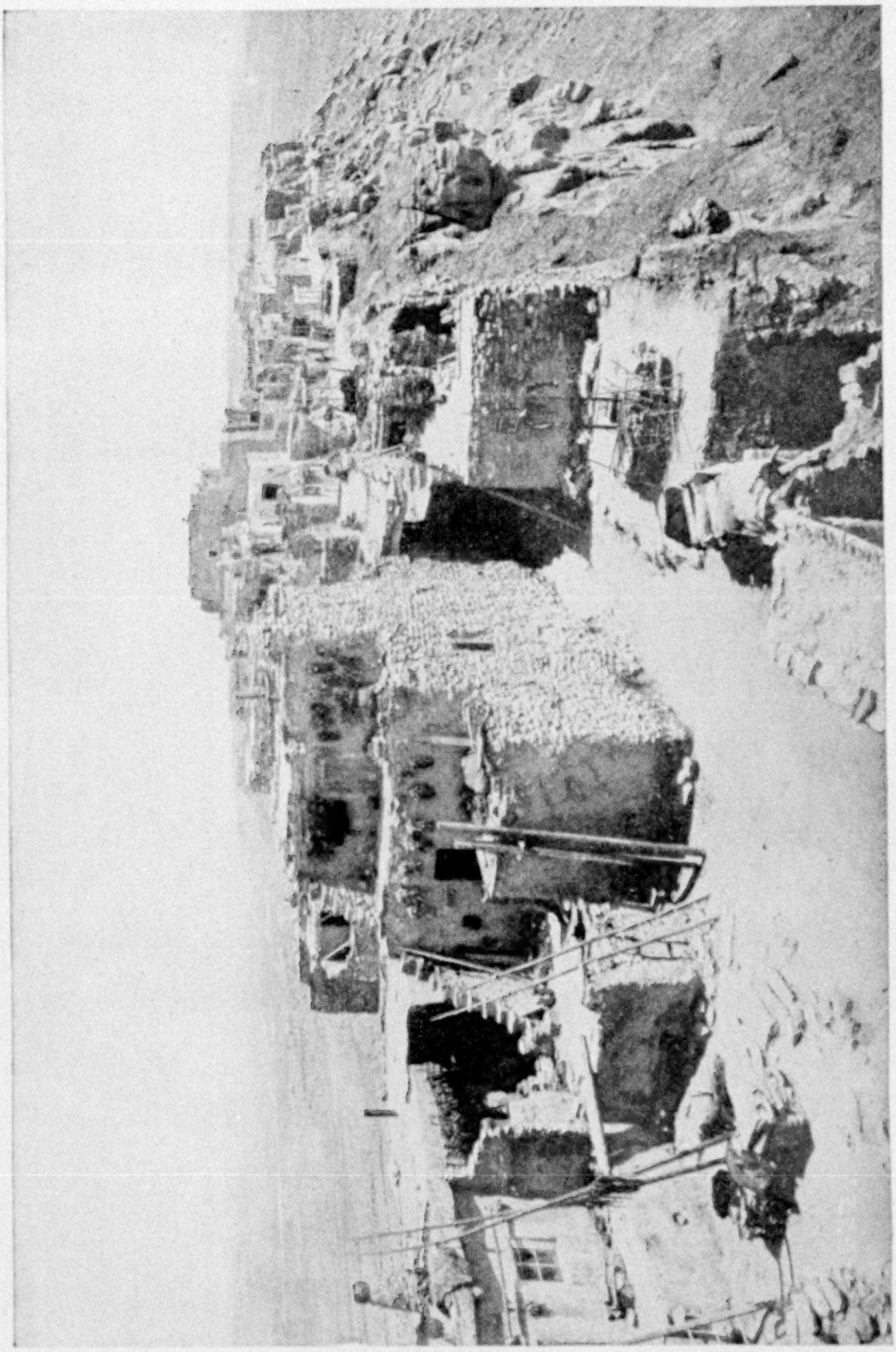
We found a cool spot in the shadow of a house and ate our luncheon before exploring the village. The village was delightfully foreign, and I had to keep pinching myself to make sure that it was not all a dream. The doors of the low adobe houses were open and one could

XUM

Photo by Mrs. Herbert Wadsworth

A TYPICAL PUEBLO IN HOPILAND, WALPI, PERCHED ON A TOWERING MESA IN A WIDE EXPANSE OF DESERT

All the Hopis are mesa dwellers, their villages being situated on great rock tables, which rise hundreds of feet above the surrounding desert, and can be reached only by steep, precipitous trails



ANOTHER VIEW OF THE PUEBLO OF WALPI, ON A MESA A FEW MILES FROM ORAIBI

Photo by A. C. Vroman, of Pasadena, California

Photo by Mrs. Herbert Wadsworth

"Oraibi looked like some gigantic fortress, looming in the distance above miles and miles of desert sand. We pitched our camp at the foot of the mesa."

look in without feeling that one was prying.

In one house I saw the village ceremonial hair-dresser doing the young maiden's hair, for unmarried maidens do their hair in a style of their own, in a big round coil over each ear, to represent the squash blossom.

In another doorway was a young squaw with the fattest and brownest baby I have ever seen. He was as naked as the day he came into the world, and was eating, much to my horror, a melon almost as big as himself.

The next house I looked into I received quite a shock, for, instead of seeing some Indian child or some home scene, a little gray burro's face looked back at me. He seemed quite at home in the room.

Along the outer edge of the village were little corrals, and there were many more burros and many sheep. We walked past the kivas, or underground chapter houses, of both the Antelope and Snake clans, but were not allowed to look, much less to go down, as the priests were praying and preparing themselves for the dance.

I found some one who understood the origin and meaning of the dance, and, returning to the plaza, we climbed up on one of the near-by roofs, from which we had a splendid view of the tepee-like altar of green leaves, and could look beyond over the roofs to the great ladder leading out of the Snake kiva, and beyond again over the edge of the mesa, over miles and miles of desert sand, to the distant blue San Francisco Mountains. While waiting for the ceremony to begin, he told me somewhat of its origin and religious meaning.

"It seems that the Hopis believe that long, long ago all mankind came up from the lower world to the earth's surface through a part of the Grand Canyon of the Colorado River. As the various families emerged, some went north, some south, and some west and east. Those that went north, the Hopis, were driven back by fierce cold which they encountered, and built themselves houses at a place called To-ko-na-bi. But, unfortu-

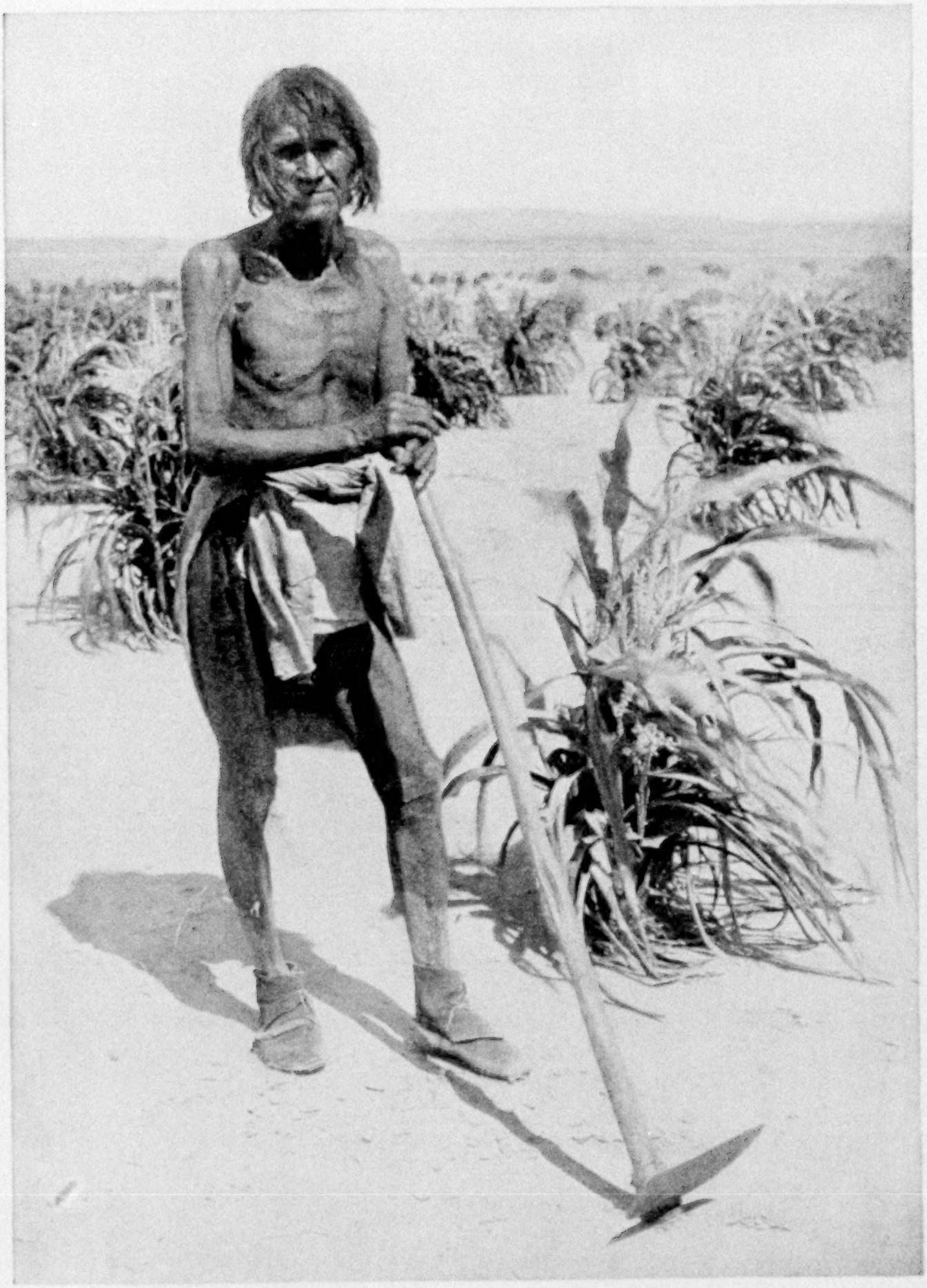
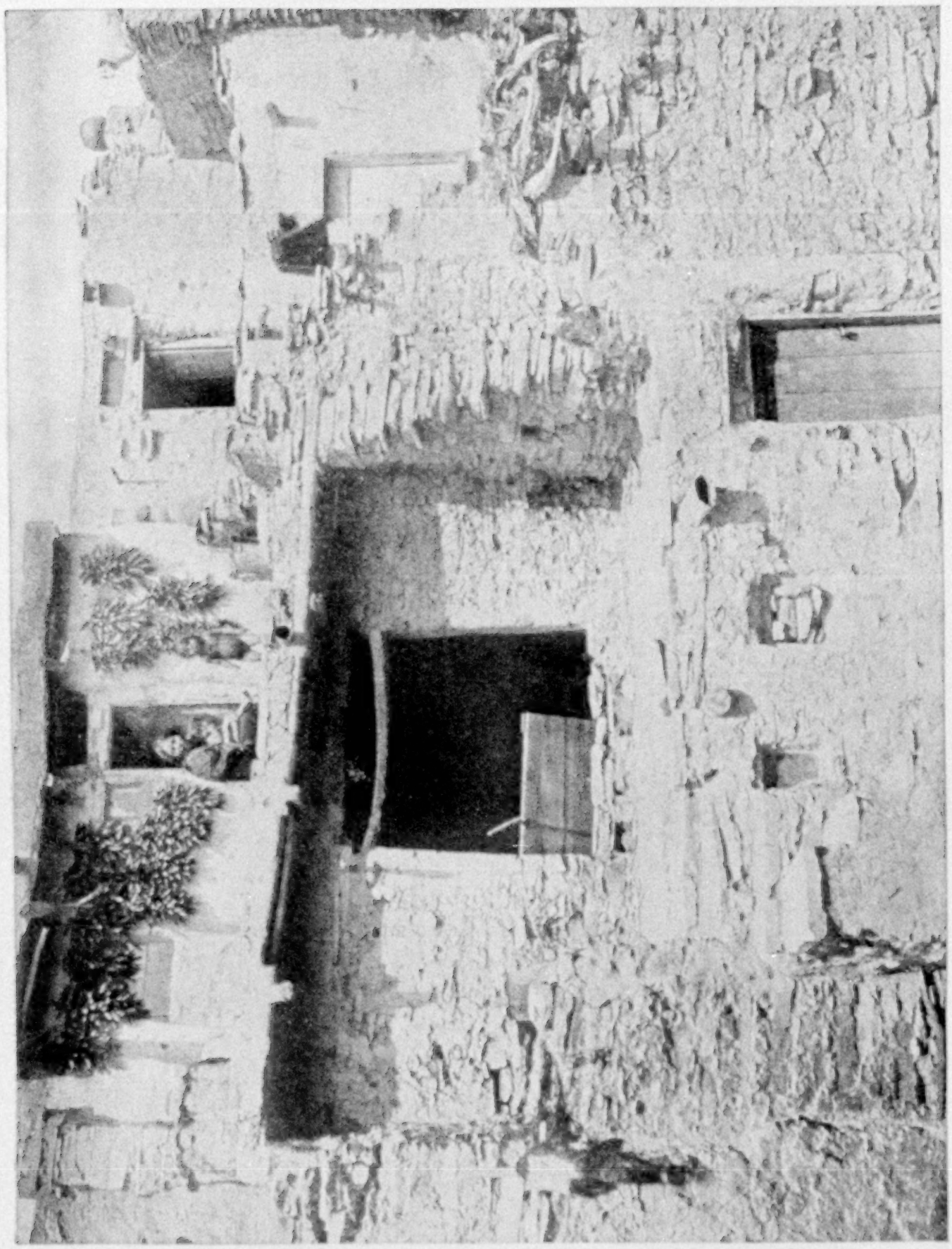


Photo by A. C. Vroman, of Pasadena, California

"At the foot of the great rock on which the town was built were little patches of corn and a few peach trees, tiny gardens which looked parched and stunted in the hot sun of the desert."

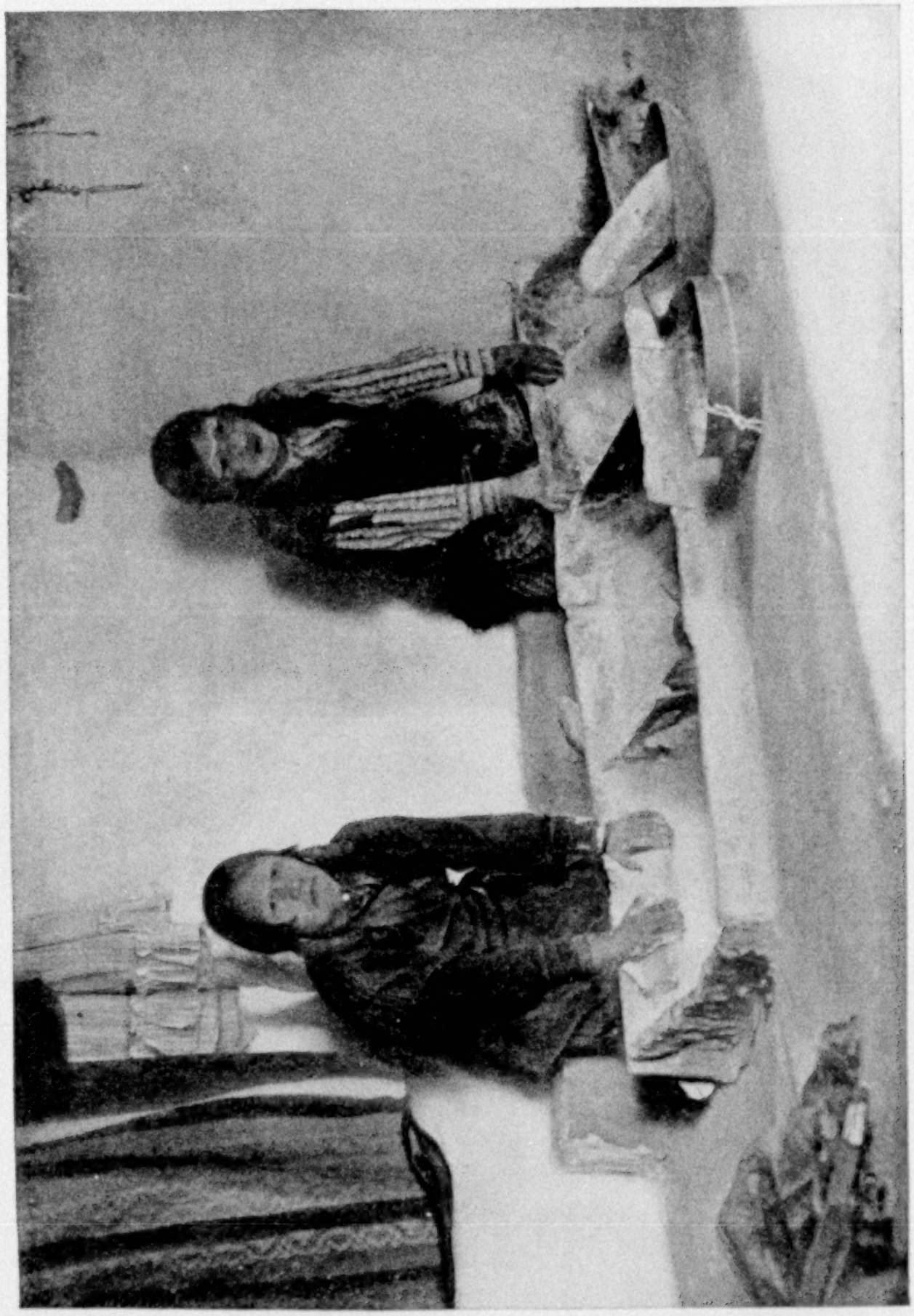
A STREET IN ORAIBI

Photo by A. C. Vroman, of Pasadena, California

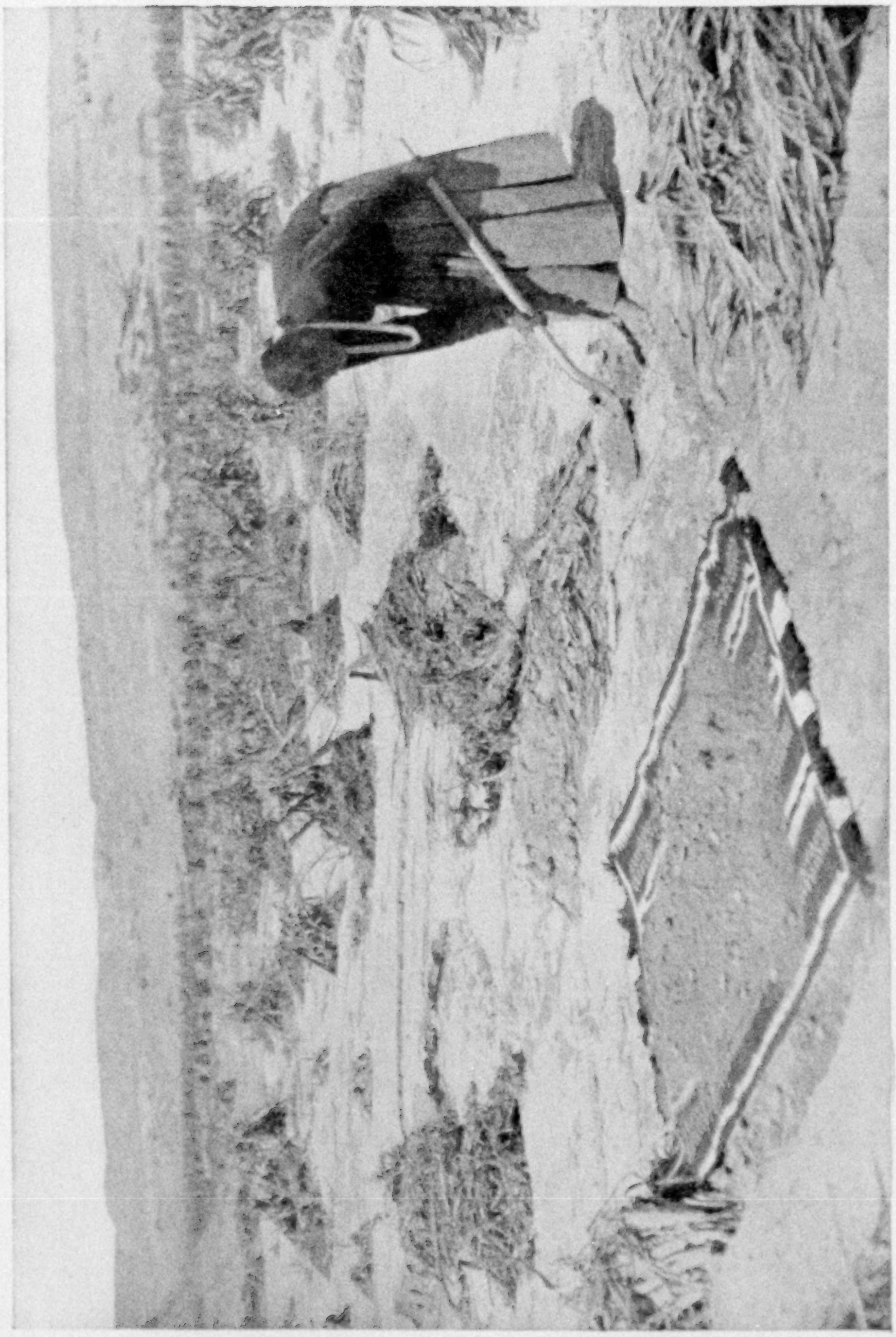


A THREE-STORY HOUSE AT ORAIBI

Photo by A. C. Vroman, of Pasadena, California



GRINDING CORN AT ORAIBI Photo by H. E. Hoopes, of Media, Pennsylvania



CLEANING A NEW BLANKET IN HOPILAND Photo by A. C. Vroman, of Pasadena, California

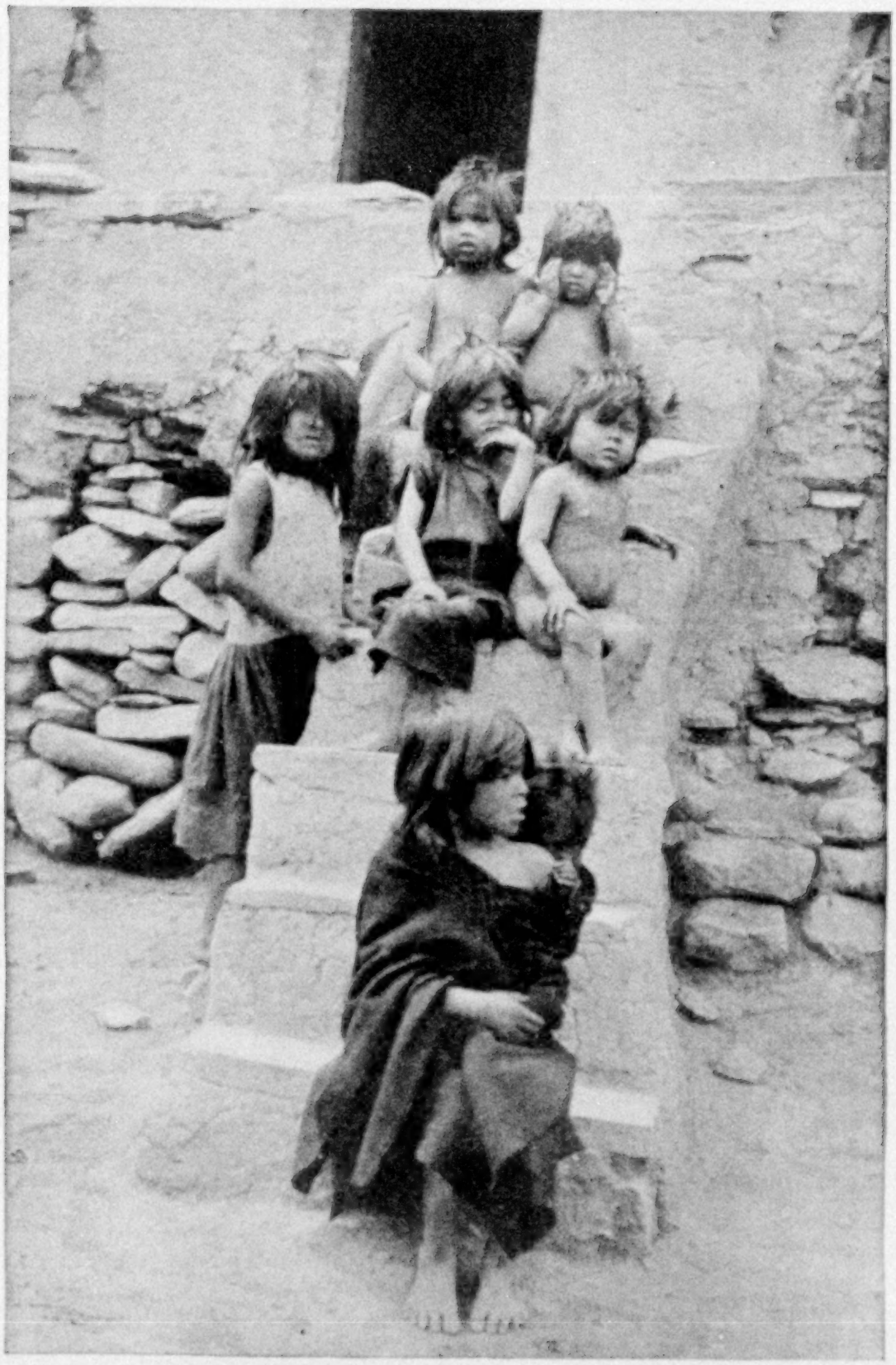


Photo by A. C. Vroman, of Pasadena, California

ON A DOORSTEP: ORAIBI

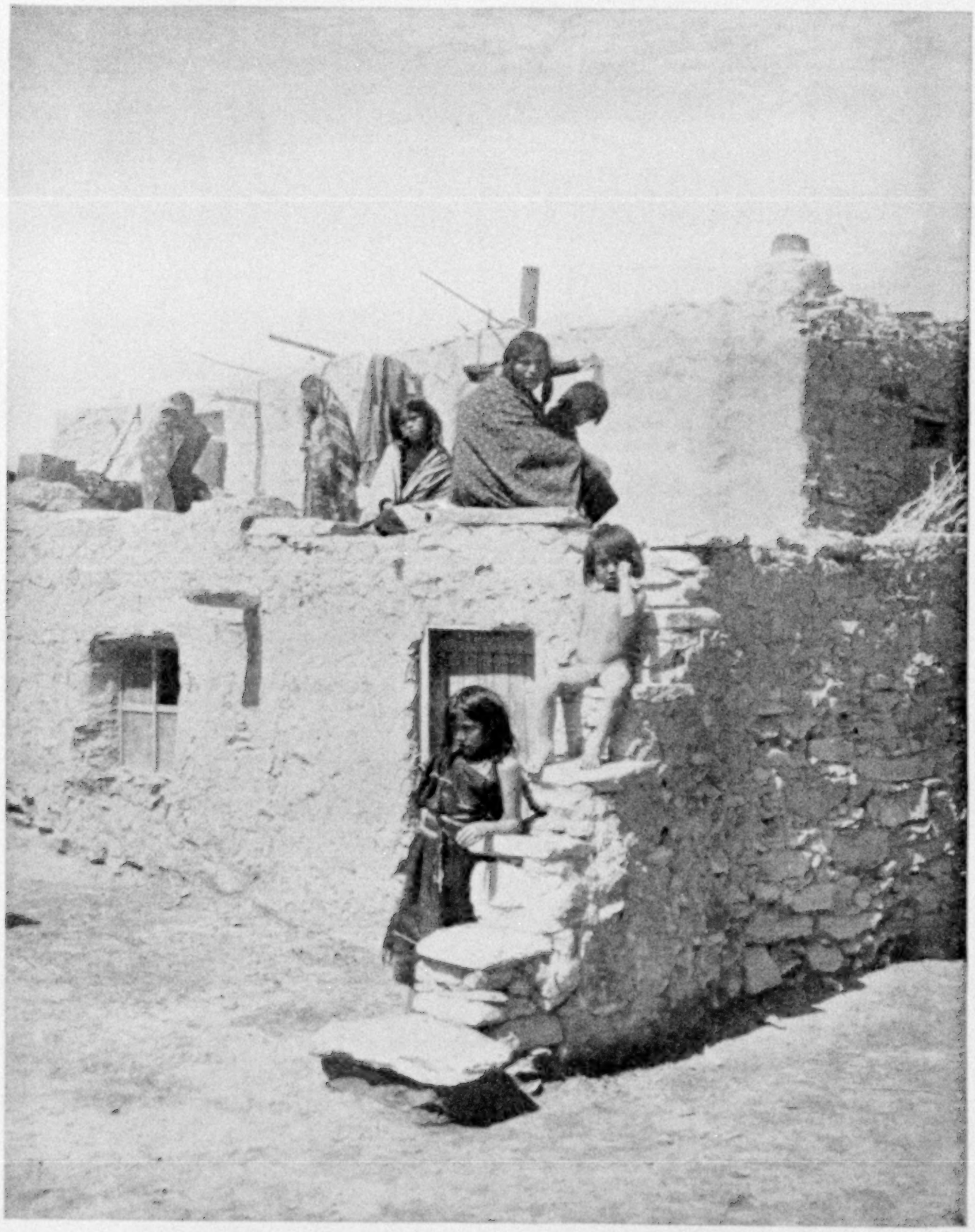
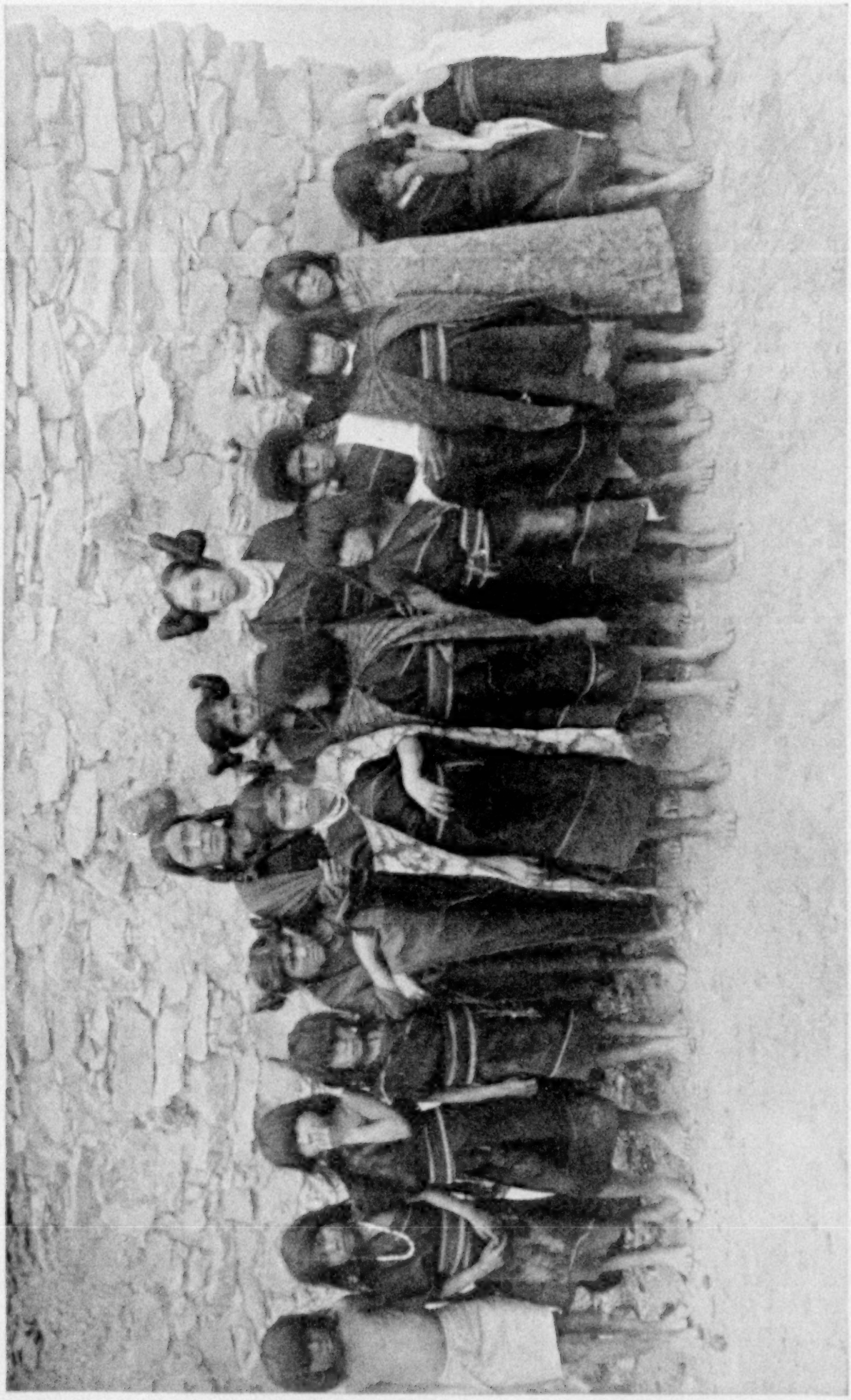


Photo by H. E. Hoopes, of Media, Pennsylvania

SCENE IN ORAIBI



GIRLS OF HOPILAND

Photo by A. C. Vroman, of Pasadena, California

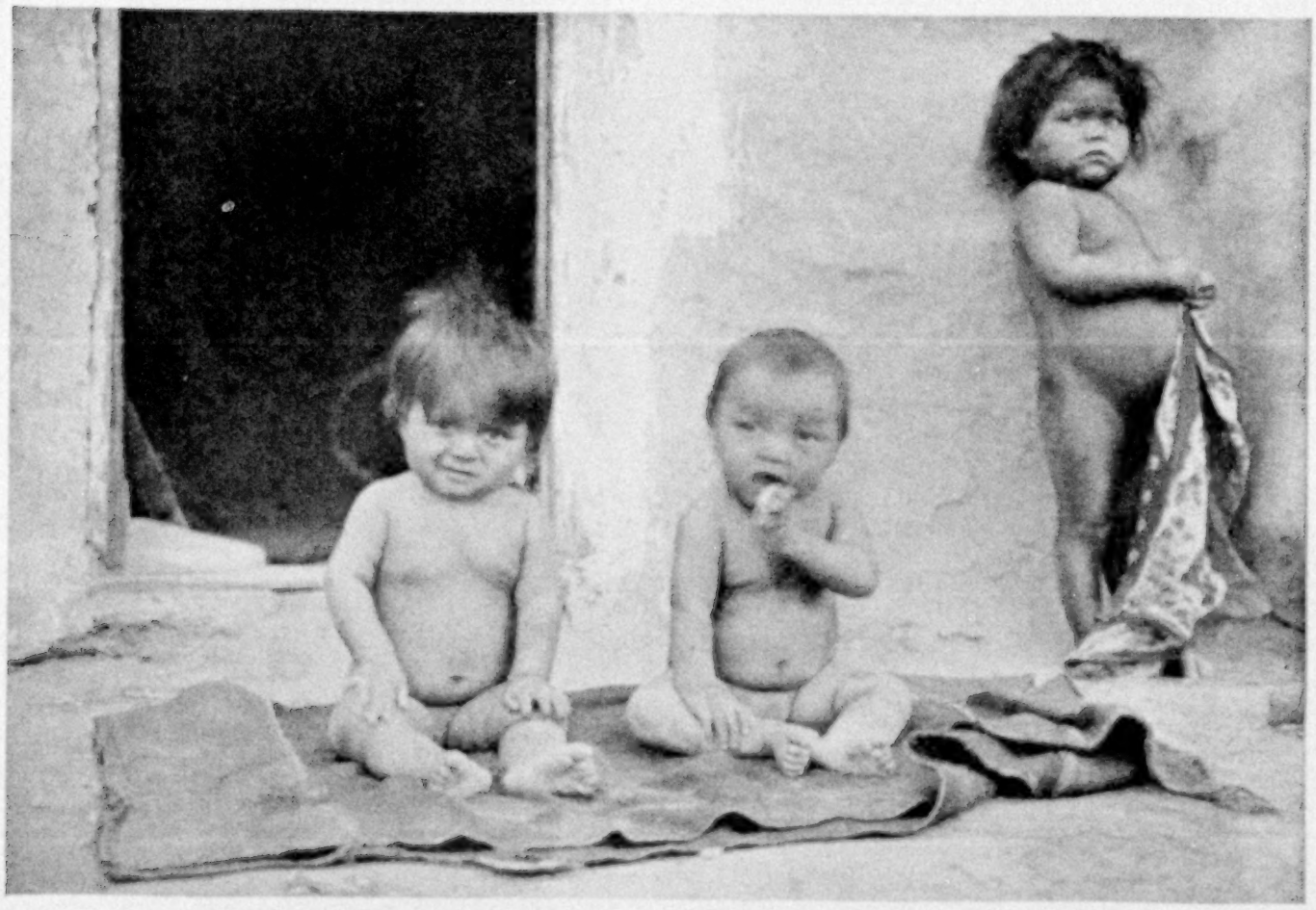


Photo by A. C. Vroman, of Pasadena, California

CHILDREN OF ORAIBI

nately, this was a desert place, where no rain fell and the corn could not grow.

"The chief of this village had two sons, the elder of whom, 'Tigo,' resolved to return to the underworld where he could learn of the gods how to be always assured of their favor. He made for himself a coffin-like boat of a hollow tree, into which he sealed himself and was thrown into the Colorado River, which he was convinced would carry him down to the home of the gods. His rude boat dashed down the rapids and over the falls into the secret bowels of the earth.

"At last it came to a stop, and Tigo, looking out of his peep-hole, saw the Spider Woman, who invited him to enter her house. The Spider Woman is a great personage in the Hopi faith. She it is who catches the clouds into her web in the heavens and makes the rain possible. Tigo accepted her invitation and she gave him the power of invisibility. She led him to descend still lower into the earth, until he reached the Snake-Antelope people. Here he was received with great cordiality and learned all the necessary ceremonies for making the rain-clouds come and go, the ripening winds to blow, and order the coming and going of the animals.

"With words of affection the chief of the Snake-Antelope clan gave him many things from both the kivas, and also two maidens, both of whom knew the snake-bite charm liquid, and instructed him that one was to be his wife and one the wife of his brother, to whom he must bring her in safety. Then, finally, he gave him the sacred standard, 'the ti-poni,' and told him that it must be revered and protected, and in all his prayers and worship it must be at the head of his altar, or his words would not reach 'Those Above.'

"Tigo now started on his homeward journey, and when he reached the Spider

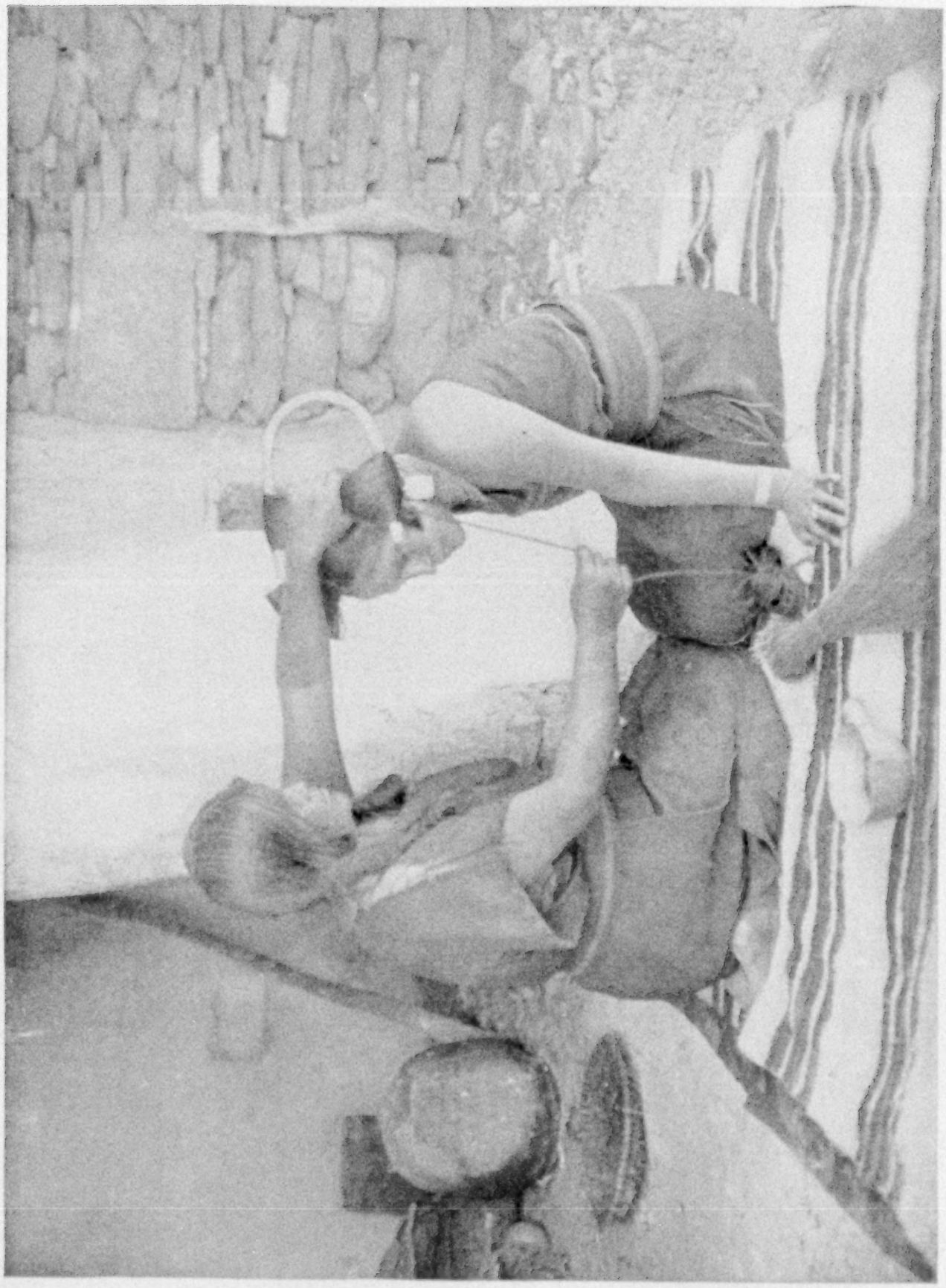


Photo by P. G. Gates, of Pasadena, California

DRESSING THE HAIR OF A HOPI MAIDEN FOR THE SNAKE DANCE

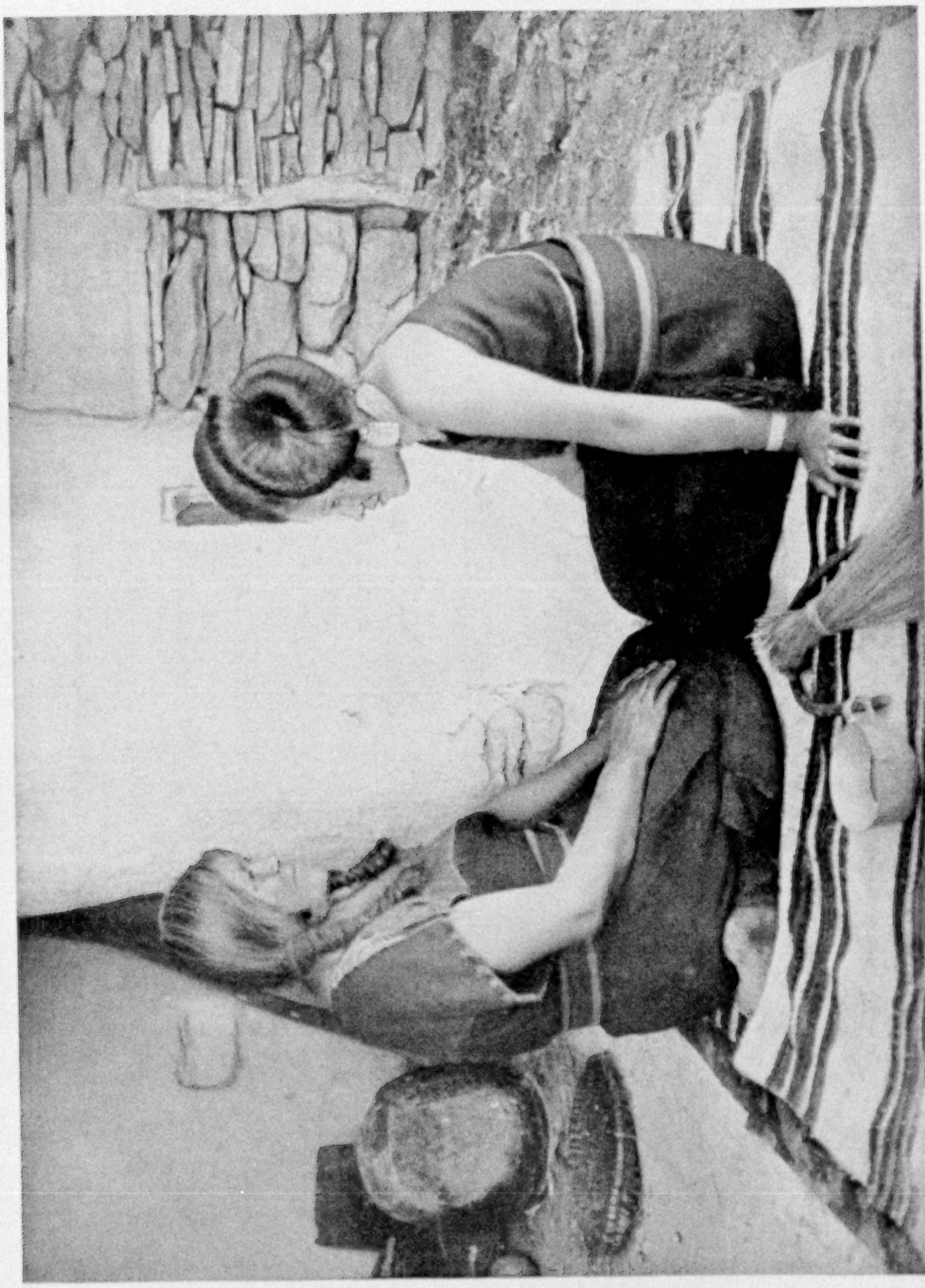


Photo by A. C. Vroman, of Pasadena, California

THE HAIR-DRESSING COMPLETED: GREAT WHEEL-LIKE COILS TO RESEMBLE THE SQUASH BLOSSOM

Photo by P. G. Gates, of Pasadena, California

A HOPI BELLE, DRESSED FOR THE SNAKE DANCE

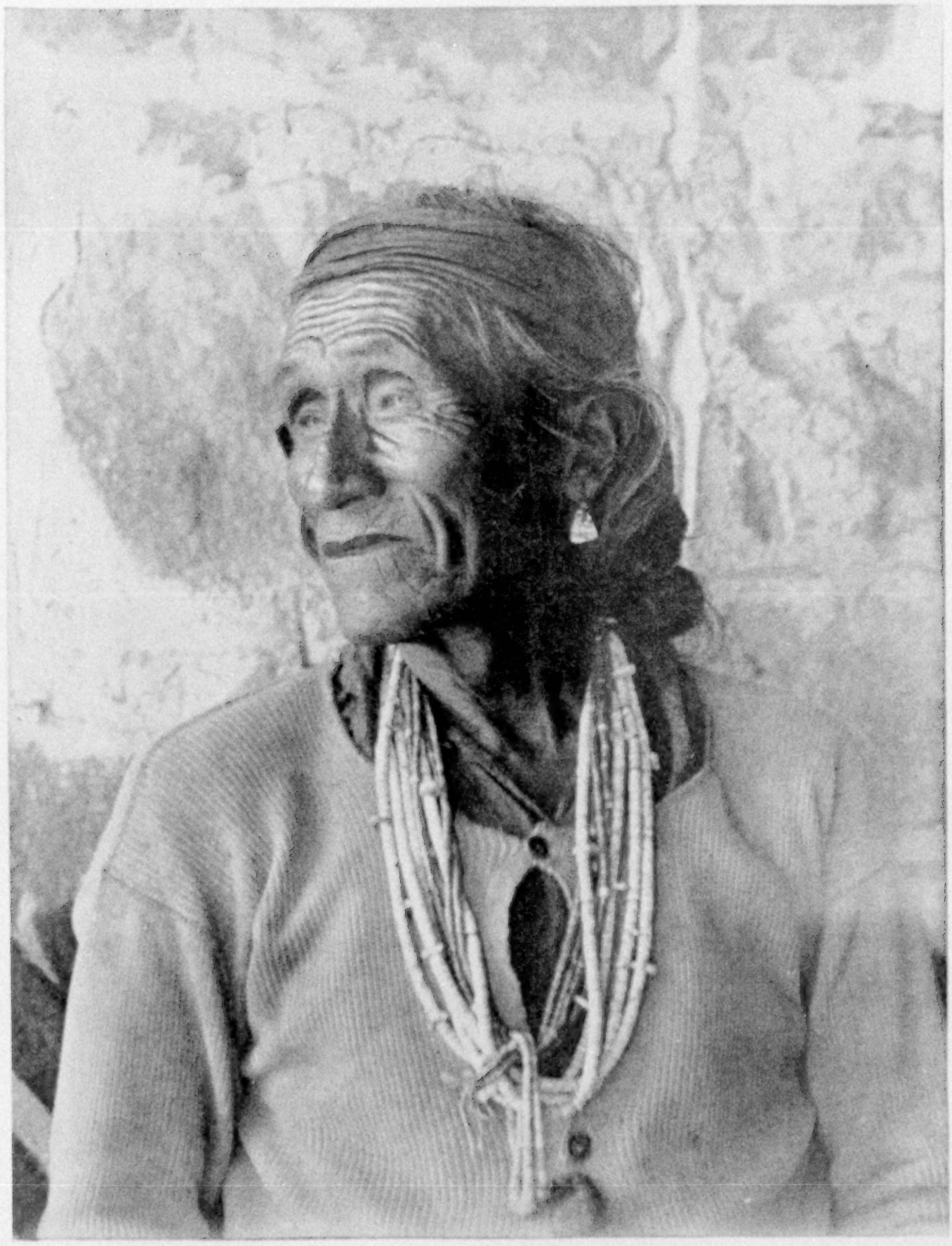


Photo by A. C. Vroman, of Pasadena, California

A HOPI CHIEF

Photo by A. C. Vroman, of Pasadena, California

A SNAKE PRIEST DRESSED FOR THE DANCE

Note the crown of feathers on his head. With the feather in his right hand he charms the snakes

Woman's home she wove a deep basket, into which she packed Tigo and the two maidens, and then, letting down part of the web from the clouds and attaching it to the basket, the clouds drew them up safely to the upper world. Tigo gave the younger maiden to his brother and announced that in 16 days they would celebrate the marriage feast. On the fifth day after the announcement the Snake people from the underworld came to the upperworld, went to the kivas, and ate corn pollen for food. Then they left the kivas and disappeared.

"But Tigo and the maidens knew that they had only changed their appearance and were in the valley in the form of snakes. So he commanded his people to go into the valley and capture them, bring them to the kivas and wash them, and then dance with them. Four days were spent catching them from the four quarters; then with solemn ceremony they were washed, and while the prayers were offered the snakes listened to them, so that when at the close of the dance, where they danced with their human brothers, they were taken back to the valley and released; they were then able to return to the underworld and carry to the gods there the petitions that their human brothers had uttered on the earth."

This was the origin and meaning of the unique ceremony we were to witness. I was so interested in the legend that before I knew it the sound of a whirring noise made me look up, and then I saw that the sun was setting and at last the time for the dance was come.

The whirring noise became louder and around the corner of the plaza appeared the priests of the Antelope clan, the harvest priests. They were naked to the waist, and were painted a warm red brown; from each shoulder and breast ran a white zigzag line to represent the lightning. They wore a kilt, which came to just above the knee; a gray fox skin hung behind, the tail almost touching the ground; necklaces of silver and beads were their ornaments. The chief Antelope priest had in his hand a weird wind instrument, which as he swung sounded like the angry, soughing wind of a storm. Many of the other priests carried rattles which made the sound of falling rain; others had ears of corn, or others harvest emblems.

Suddenly my companion caught my arm and said, "Look!" Following his pointing finger, I saw a priest ascending the ladder leading from the Snake kiva. He was covered with a long coat and carried a great bag, the contents of which writhed and wriggled. He came quickly into the plaza, deposited his bag of snakes under the tepee-like altar, and returned to the kiva.

I kept my eyes glued to the ladder, for I knew that the Snake priests had to come up that way, and I was rewarded, for just as the rays of the setting sun struck the top rung of the ladder a wild figure emerged, dressed more or less like the Antelope priests, but with long, flowing hair, crowned with masses of feathers. As he reached the top of the ladder he took a handful of sacred meal from his pouch, and with a splendid free gesture he flung it, with up and outstretched arm, towards the sinking sun and for a second stood like a bronze statue with arm uplifted as the meal, a tiny white cloud, floated downward over the edge of the mesa. Then he turned and stepped into the narrow street and another took his place, and another, and another, until all had left the kiva; then quietly and without any hurry they marched into the plaza and took their stand just opposite the altar, facing the Antelope priests. Then the chief priest of the village took some sacred meal and made a line with it between the Snake and Antelope priests.

Now the ceremony began. Crossing hands, they swayed from east to west with eyes half closed. After about 20 of these motions they burst into a deep-voiced chant, stamping with the left foot upon the ground. Next they swayed from west to east and again gave voice to the queer, low chant. I got a little nearer and heard that as they swayed they were praying in low tones.

XUM

THE ANTELOPE PRIESTS: ORAIBI

Photo by A. C. Vroman, of Pasadena, California

"They were naked to the waist, and were painted a warm red brown; from each shoulder and breast ran a white zigzag line to represent the lightning. They wore a kilt, which came to just above the knee; a gray fox skin hung behind, the tail almost touching the ground; necklaces of silver and beads were their ornaments." They hold rattles in their hands (see page 125).

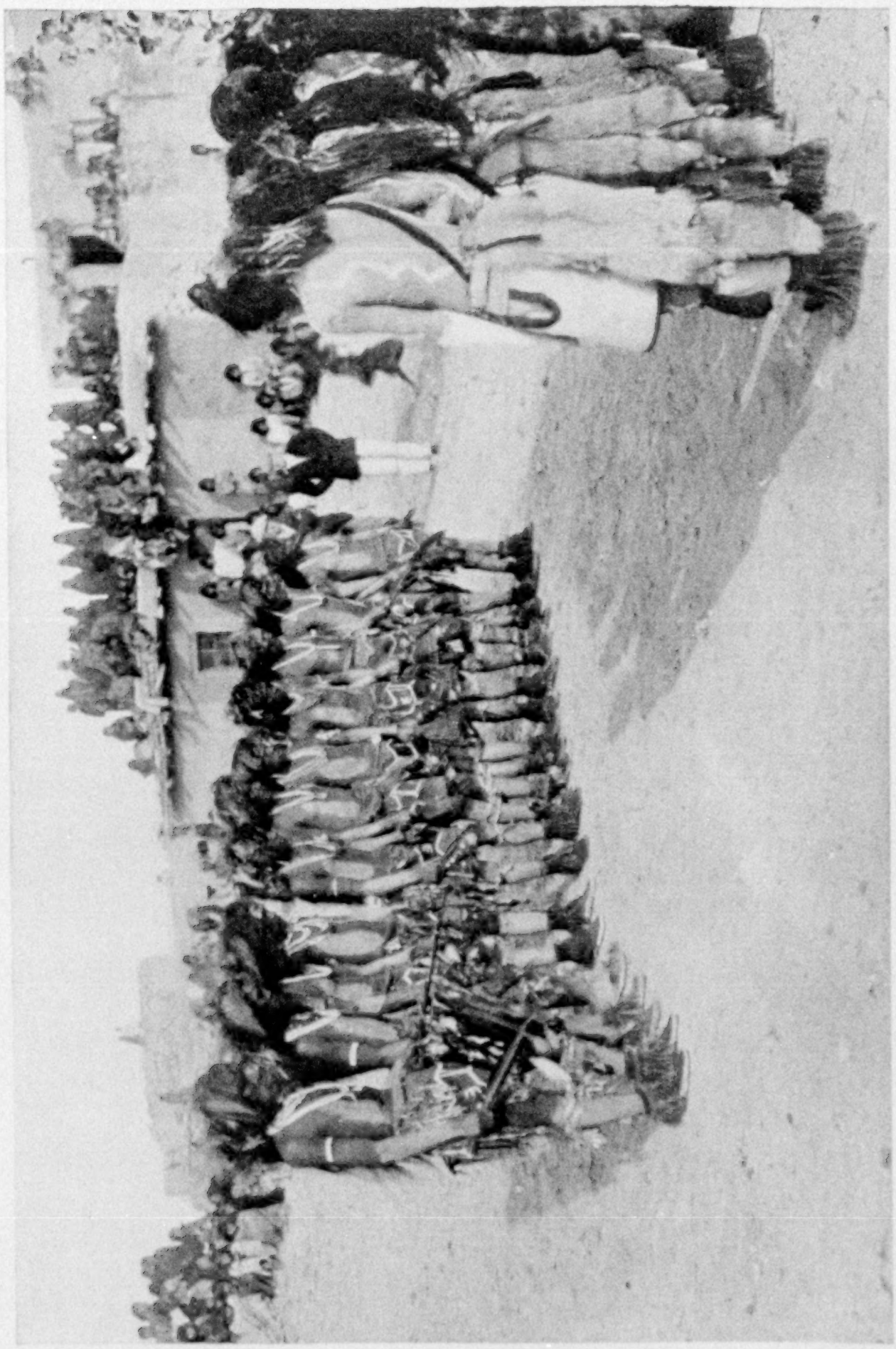


Photo by A. C. Vroman, of Pasadena, California

THE SNAKE PRIESTS TOOK THEIR STAND JUST OPPOSITE THE ALTAR FACING THE ANTELOPE PRIESTS (SEE PAGE 125)

THE SNAKE PRIESTS IN LINE BEFORE THE ALTAR Photo by A. C. Vroman, of Pasadena, California

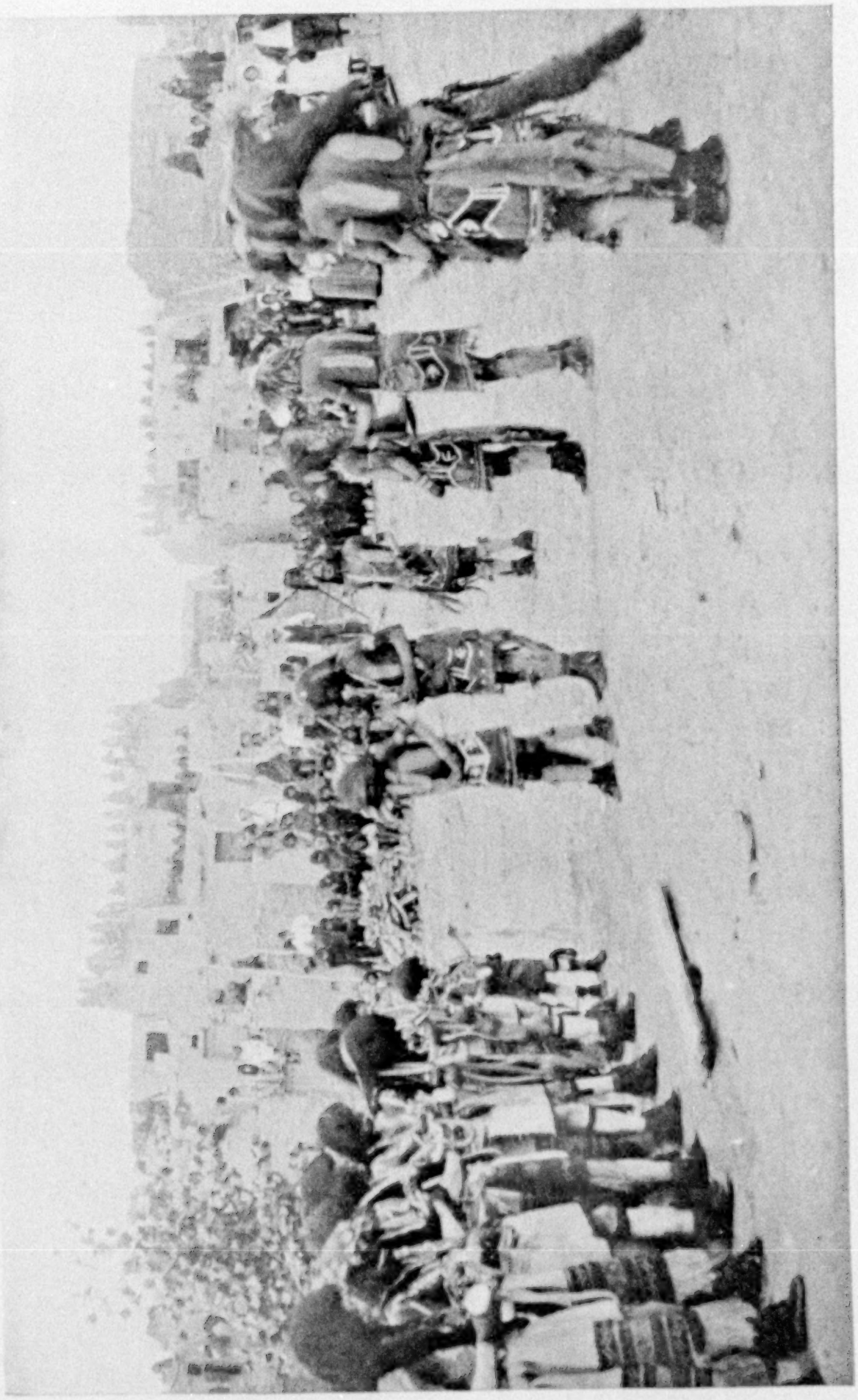
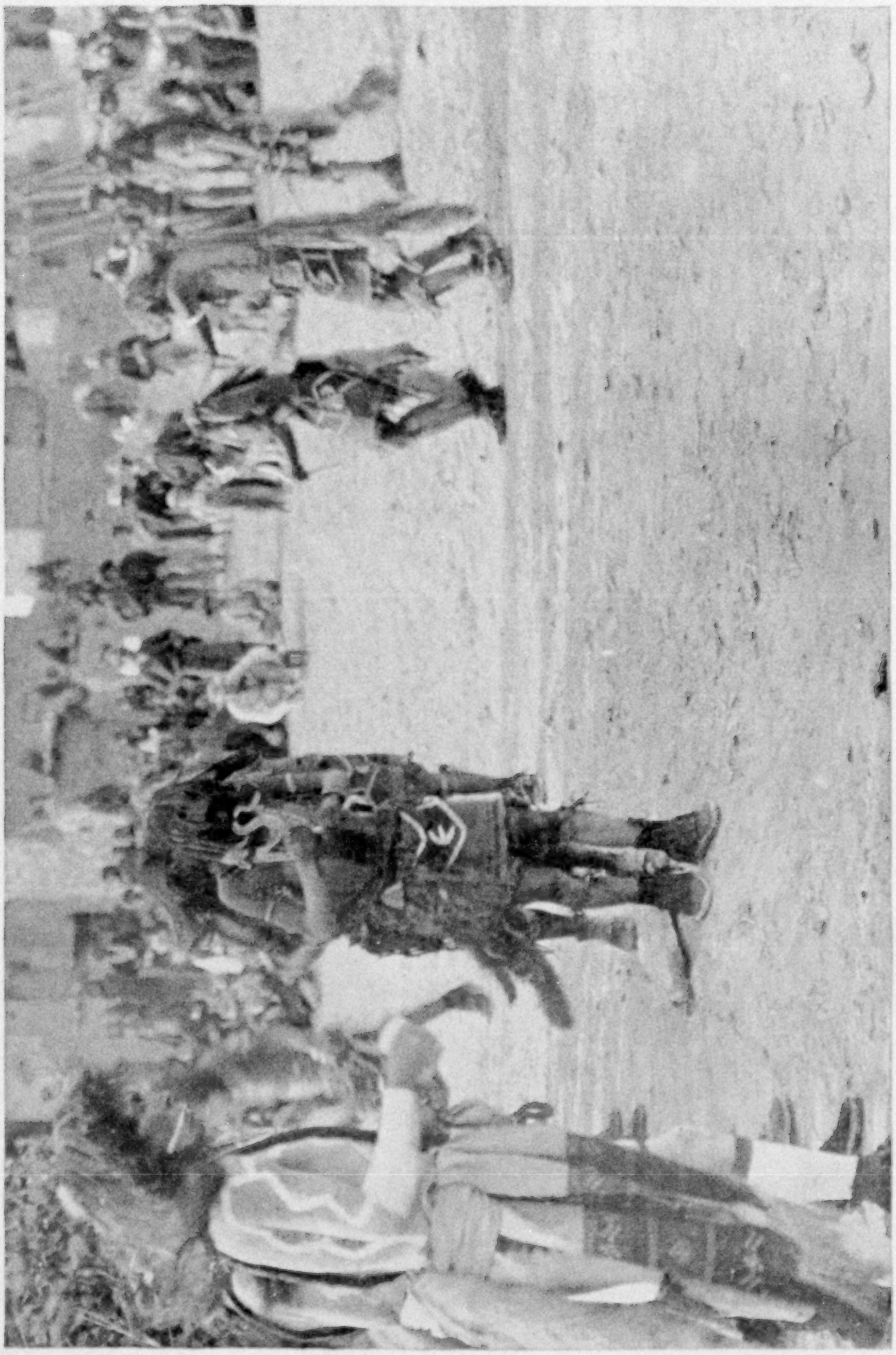


Photo by A. C. Vroman, of Pasadena, California

"As they passed the altar they paused and stamped twice on a board that was over a hole in the ground . . . to awaken the spirits of the underworld to hear their prayers" (see page 131)



"EVERY OTHER MAN HAD A SQUIRMING LIVE RATTLESNAKE IN HIS MOUTH" (SEE PAGE 131)

Photo by A. C. Vroman, of Pasadena, California

After a while some of the priests began to look half hypnotized, and sang with their eyes fixed and heads bent. The silence, except for the chanting, was getting on my nerves. I looked around and saw crowds of people, all silent; even our troopers were quiet. Suddenly the singing stopped and the Snake priests stood in line, single file, only every other priest had his hand on the shoulder of the one in front of him and in the other hand carried a wand of eagle feathers. Four other Snake priests stationed themselves at the four points of the compass.

Then suddenly the "Antelope Clan" began another chant, louder and far wilder than before. They stood in front of the altar, swaying forwards and backwards. At about the second stanza the Snake priests began to move; around they went, around the plaza, with a funny, high-stepping motion. As they passed the altar they paused and stamped twice on a board that was over a hole in the ground.

I asked my companion what it meant, and he said that the Hopis believe that that hole leads to the underworld and they are awakening the spirits to hear their prayers.

The second time the priests passed the altar I saw them pause, but only when they had turned facing me I realized the horror. Every other man had a squirming live rattlesnake in his mouth! The snakes were curling themselves into all kinds of horrible shapes, and their evil heads went darting this way and that.

I saw one rattler strike a man just under the ear. He had to pull it loose, but took a fresh hold of the snake nearer its head and seemed none the worse for it.

Now I saw the reason for the second priests with the feather wands. Their duty was to soothe the snake by stroking it with the feathers, and to guide the snake-carrying priest, who often looked as if he was in a trance. Once around the plaza they would dance with their ghastly burden, and then, putting it down facing one of the four points of the compass, they would leave it, going on to the altar for a fresh one.

As soon as the snake was released, off it would glide, trying to get to the refuge of one of the houses, or into the crowd which surrounded the plaza like a living wall; but, before it could reach either, the priest stationed at that point would come behind it and stroke it with a feathered wand similar to those of the guiding priests. The snake would hiss and try to coil and strike, but the tickling of the feathers would make it un-

Photo by Mrs. Herbert Wadsworth

"I saw one dancing with a bull snake bigger than himself, and the little boy had to hold it with both hands, as well as with his teeth, to prevent it from getting away (see page 133).

Photo by Mrs. Herbert Wadsworth

"Every other priest had his hand on the shoulder of the one in front of him, and in the other hand carried a wand of eagle feathers. Their duty was to sooth the snake by stroking it with feathers, and to guide the snake-carrying priest who often looked as if he was in a trance." The tepee-like altar and the great bag which contained the snakes are clearly shown in the picture.

Photo by Mrs. Herbert Wadsworth

After dancing once around the plaza, the priest places the snake on the ground and goes to the altar for a fresh one (see page 131)

coil; then, with a long swing of the arm, the priest would pick it up with about as much unconcern as most people would pick up a rope.

Two of the Snake priests were little boys who were serving their novitiate, and who could not have been more than eight years old. I saw one of them dancing with a bull snake bigger than himself, and the little boy had to hold it with both hands as well as with his teeth to prevent it from getting away.

The chanting became louder and louder, and on and on went the priests until every snake had been danced with.

A group of Hopi maidens now entered the plaza. Their hair was done in the great wheel-like coils on either side of their heads, to resemble the squash blossom, and they were dressed in their very brightest and best and carried ceremonial baskets filled with sacred meal. As they neared the altar the priests rushed forward and threw all the snakes on the ground in a great squirming mass at their feet, and the maidens sprinkled the hideous reptiles with the meal.

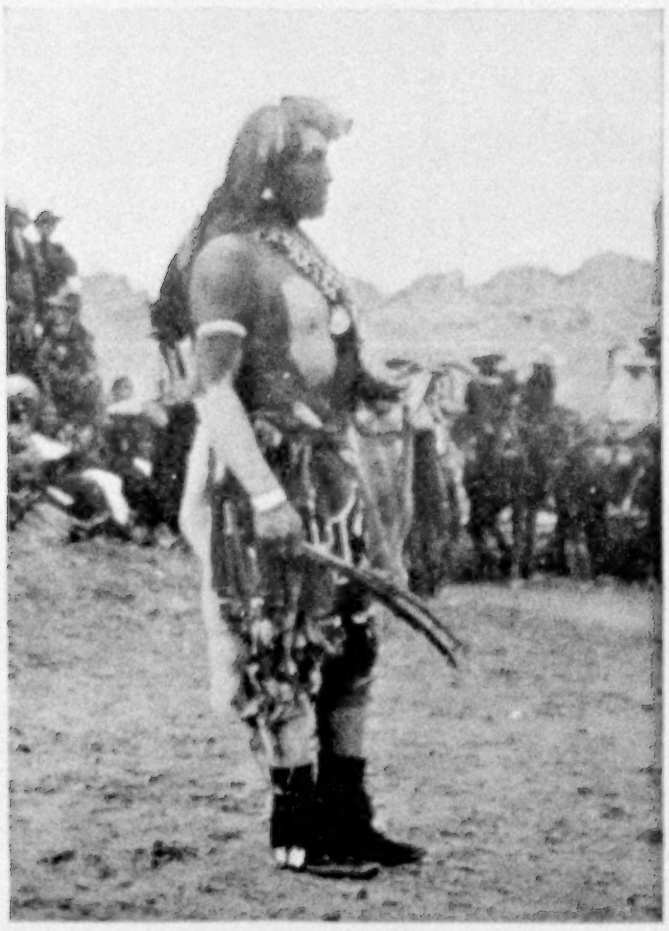


Photo by Mrs. Herbert Wadsworth

One of the four snake priests who was stationed to gather up the snakes that had been danced with (see page 131).

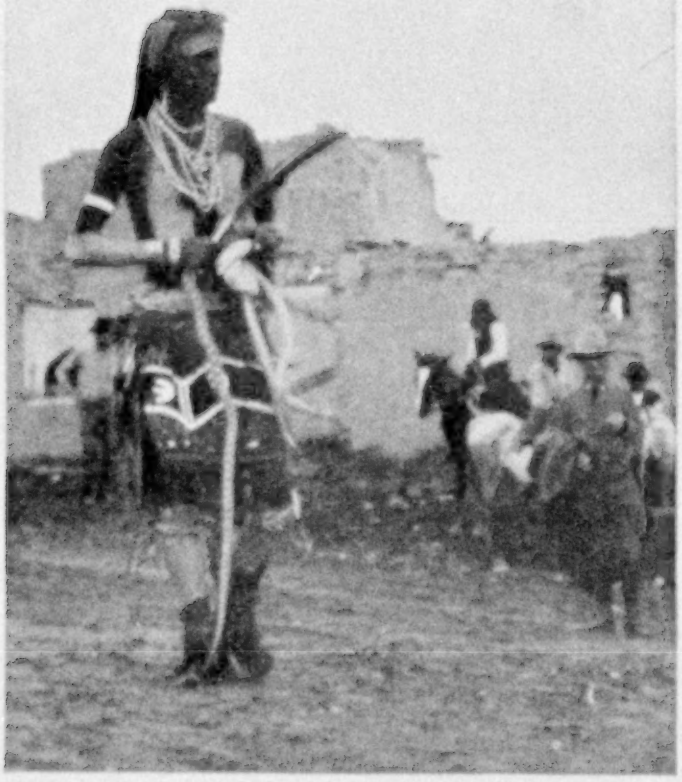


Photo by Mrs. Herbert Wadsworth

A SNAKE PRIEST, ORAIBI: NOTE THE LONG SNAKE HELD IN THE LEFT HAND

Then, at a signal from the chief priest, the Snake priests bent down and each seized two handfuls of snakes, and turning ran with incredible swiftness out of the plaza, some to the north, some south, some east and west. We watched and saw them rush over the mesa and down its almost perpendicular sides until they reached the desert. There with a parting message to their spirit brothers they left them at the four points of the compass to go whither they would.

Then, mounting the mesa once more, the priests halted where some hollowed-out rocks had formed basins and had caught the rain-water. There they stripped and washed off the ceremonial paint. Then, to my dismay, they drank something that proved to be a strong emetic, and for a few minutes I found

Photo by Mrs. Herbert Wadsworth

A SNAKE PRIEST TICKLING A SNAKE WITH FEATHERS TO MAKE IT UNCOIL
(SEE PAGE 131)

Photo by Mrs. Herbert Wadsworth

The priest holds two rattlesnakes in his left hand. With the feathers held in his right hand he has been stroking the snake on the ground, thus making it uncoil, and he is now about to seize it (see page 131). Oraibi.

Photo by A. C. Vroman, of Pasadena, California

THE END OF THE SNAKE DANCE: WAITING FOR THE HOPI MAIDENS TO BRING THE SACRED MEAL

The stooping figure in the left foreground is about to recover the snake on the ground by first tickling it so that it will uncoil

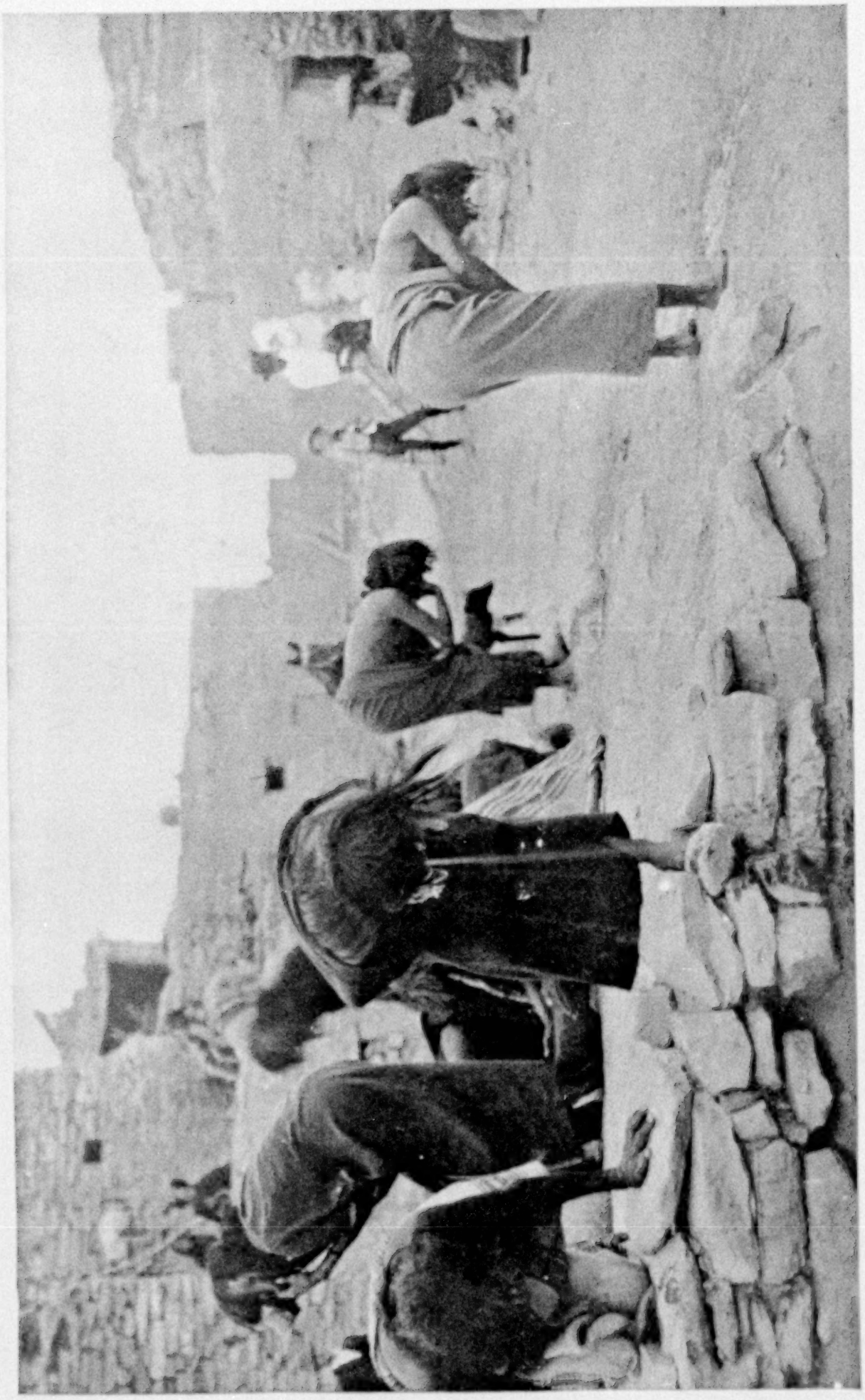


Photo by A. C. Vroman, of Pasadena, California

THE PURIFICATION AFTER THE DANCE WITH THE SNAKES (SEE PAGE 137)

it best to look away and think of more pleasant things. At last their purification was over and on they came. Running very swiftly, they passed us like a brown flash, and then, with a last farewell gesture to the now almost-vanished sun, their kiva swallowed them up and I realized the dance was over.

I rode back to camp very silent, the whole thing leaving me rather dazed, it seemed so weird, so unreal; and yet the knowledge that the dance was the culmination of 16 days of fasting and prayer, and the intense religious attitude of both priests and people, impressed me more than I was willing to admit.

How was it that the poison of the snakes had no effect on the dancers? I asked many for the solution of this problem, and their answers were always the same, "We don't know; all we know is, if any trader or sheep-herder is bitten by a rattler, if we can get them to the Snake priests they are always saved. The cure, whether drug, herb, or incantation, is kept secret, and the Snake clan guard it as a sacred trust, never to be divulged under any conditions."

It was with real regret we broke camp next day, and, as we rode across the desert, for several hours I kept looking back at the mesa and the little Hopi town, clothed in a dignity of its own, holding the faith of its forefathers unchanged, unmoved by the centuries of civilization.

TAMING THE WILD BLUEBERRY

By Frederick V. Coville

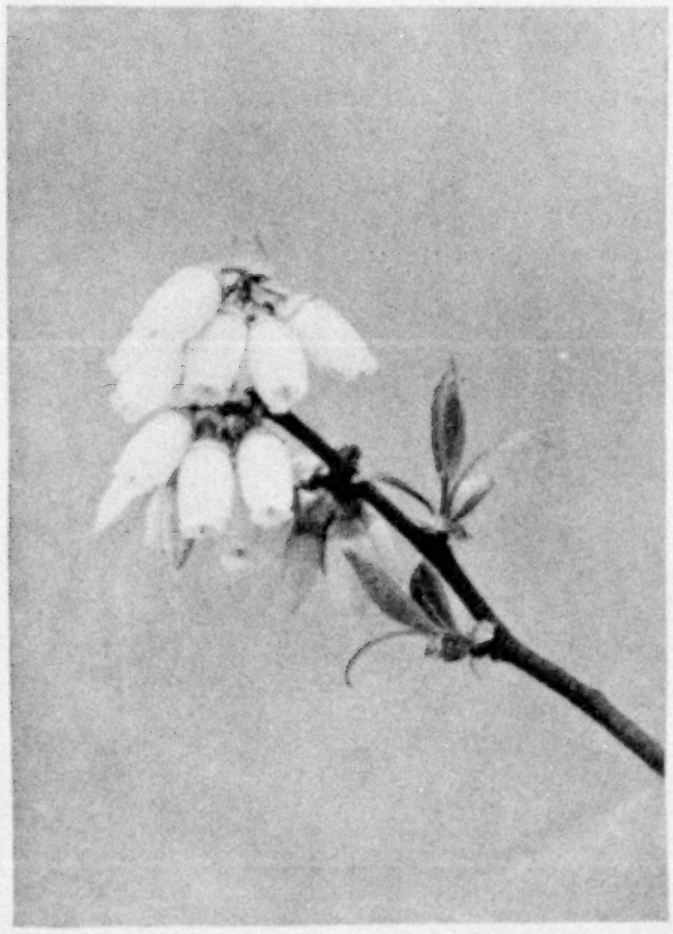
As the result of Mr. Coville's experiments with blueberries, it is very probable that in a few years blueberries will be cultivated in the United States as extensively and profitably as the cranberry. All the blueberries now used are picked wild, just as were all the cranberries not so very many years ago. Many persons in many parts of the United States now make good incomes by cultivating the cranberry. Last year, for instance, the cranberry crop amounted to about one million and a half bushels, worth three million dollars. Readers of this Magazine desiring further information on the cultivation of blueberries are referred to "Experiments in Blueberry Culture," by Frederick V. Coville, recently published by the United States Department of Agriculture as Bulletin No. 193 of the Bureau of Plant Industry.

THE "taming of the wild blueberry" has involved the pursuit of a strange and often dim trail of scientific search, in the following of which a curious chapter has been added to the ever-increasing Book of Marvels in which our knowledge of the foundations of agriculture is recorded.

The name blueberry is applied in New England to plants of the genus *Vaccinium*, which have seeds so small as to be unnoticeable when the berry is eaten, while the name huckleberry is usually restricted by New Englanders to the genus *Gaylussacia*, in which each seed is surrounded by a bony covering like a minute peach pit, which crackles between the teeth.

In the South and West, however, the name huckleberry is applied with little discrimination to the various wild species of both *Vaccinium* and *Gaylussacia*, about 40 in number. This article deals principally with the swamp or highbush blueberry, *Vaccinium corybosum*, which commonly grows from 4 to 7 feet high, and produces berries in abundance and of especially good flavor.

The wild blueberries are everywhere utilized for pies and jam and the well-beloved blueberry cake and blueberry pudding. An accurate valuation of the wild blueberry crop has never been made, but it undoubtedly reaches millions of dollars annually. In blueberry districts the yearly shipments from single small



A CLUSTER OF BLUEBERRY BLOSSOMS
(NATURAL SIZE)

towns often bring ten, or twenty, or even thirty thousand dollars, and in Northern cities, as for example Boston, New York, Detroit, and Chicago, the annual consumption is enormous.

Many attempts have been made to cultivate the blueberry for its fruit; but, when given the care, protection, and nourishment that man has found necessary for the ordinary plants of agriculture, the blueberry sickens and dies. The belief is prevalent among farmers that it is impossible to transplant the wild blueberry successfully. And it really is impossible if, as usually happens, the planting is done in the soil of a fertile garden.

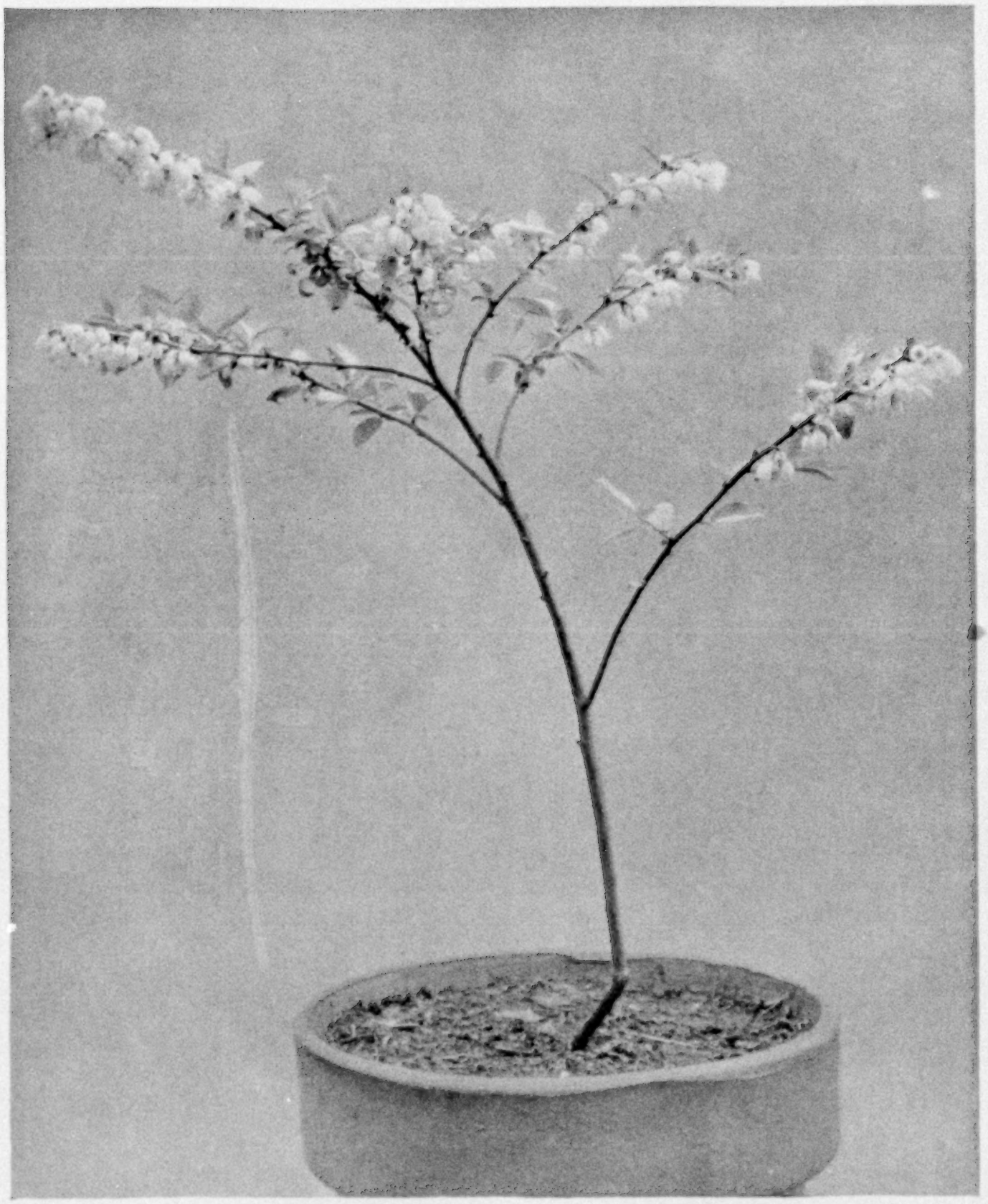
What the blueberry demands is acidity. In a soil so acid that ordinary plants die of poison and starvation, the blueberry thrives, luxuriating in flower and foliage and fruit. That a plant should grow better in an acid soil than in a fertile one is contrary to what has been regarded as one of the fundamental principles of agriculture.

Ordinary agricultural plants absorb their nitrogen from the soil in the form of nitrates. From the cumulative researches of a group of scientists who have exhaustively studied the question for a generation, it has been established that the production of nitrates in the soil is brought about by certain micro-organisms known as nitrifying bacteria; and, furthermore, that the ability of these bacteria to manufacture nitrates is destroyed by acidity. Growing as it does in an acid soil, the blueberry is therefore squarely up against the question how it shall get its nitrogen. To the individuals of the plant world the nitrogen problem brings about the same tragic situations as does the bread problem to the human race.

PLANTS THAT TRAP INSECTS FOR FOOD

One group of acid-soil denizens, the insectivorous plants, has solved the nitrogen question in a singularly direct way. They entrap insects and digest and absorb their nutritive parts. Of such habits among our native plants are the sundews (*Drosera*), the pitcher plants (*Sarracenia*), the bladderworts (*Utricularia*), the butterworts (*Pinguicula*), and the Venus' flytrap (*Dionaea*).

Another method of getting nitrogen in acid soils is represented by the European lupin. These plants have on their roots living tubercles within which grow certain bacteria. It has been found to be the function of these bacteria to take the nitrogen of the atmosphere and convert it into some chemical combination in which the lupin plant can use it. The very similar tubercle bacteria of the roots of clover and other cultivated leguminous plants have been much studied in the last 30 years, and the fact of the fixation of atmospheric nitrogen by them has been fully established and is everywhere recognized in agricultural practice. The blueberry gets its nitrogen by



A THREE-YEAR-OLD BLUEBERRY PLANT IN BLOOM

neither insect trap nor root bacteria. The microscopical examination of the plant, however, disclosed the presence of a fungus growing partly outside and partly inside the epidermal cells of the root. The fungus is exceedingly minute, the threads of which it is composed having a diameter of 0.00006 to 0.00012 of an inch. The fungus occurs in great abundance on the roots of vigorous

plants. The cells in which it is found are not swollen nor distorted, nor do their contents collapse or show any of the other effects usually produced by injurious fungi. There is no indication that the fungus is in any way obnoxious to the plant. On the contrary, the uniformity with which it has been found to occur on healthy plants and its frequent absence or scarcity on sickly plants are at once suggestive of a mutually beneficial relationship.

It is well known that fungi differ from the higher plants in being able to take their required nitrogen directly from organic nitrogen compounds. They do not require that the nitrogen they consume shall be in the form of nitrates. Fungi are particularly abundant in the decaying vegetable matter forming the leaf litter of a forest, though this litter may be distinctly acid in its chemical reaction. Indeed, they grow luxuriantly on vegetable remains containing no nitrates and of such acidity that the conversion of humus nitrogen into nitrates by means of bacteria cannot take place.

As a reasonable explanation of the phenomena presented in the peculiar life history of the blueberry, the conclusion has been reached that the root fungus extracts nitrogenous food from the non-nitrified acid organic matter with which it comes in contact and changes it into some chemical form in which the blueberry plant can make use of it. Such a transformation is analogous to that already well known to occur in the root tubercles of leguminous plants. It is quite within the range of possibility that mycorhizas, as these structures are called, consisting of a root and its symbiotic fungus, will ultimately be proved to have a very high place in agriculture as nitrogen purveyors, second only in importance to these same leguminous tubercles.

BLUEBERRIES THRIVE ONLY IN VERY ACID SOIL

The writer's experiments with blueberries, which extended over a period of four years, covered a great diversity of soil mixtures, nutrient solutions, methods of potting, amount of shade, and day and night temperatures. Glass pots were much used, to facilitate the study of the roots. A hole was bored in the bottom to give the necessary drainage, and the glass was darkened by a removable cuff of opaque gray blotting paper. The use of these glass pots resulted in an intimate knowledge of the behavior of blueberry roots under different soil conditions, which could not have been secured in any other way and which was essential to the correct interpretation of the experiments.

In a rich garden soil in which alfalfa seedlings and rose-cuttings grew luxuriantly the blueberry plants stagnated, but in an acid soil the blueberries became large and vigorous, while roses and alfalfa starved and died. Alfalfa is exceedingly sensitive to acidity and cannot be grown with success in soils that have not a somewhat alkaline reaction. When grown in the humid eastern United States, alfalfa is rarely successful, except on calcareous soils, unless the natural acidity of the soil has been neutralized by suitable applications of lime.

Heavy manuring, also, is injurious to the blueberry. Six blueberry seedlings were transplanted into glass pots in a good blueberry soil, and six more seedlings were potted in the same manner, except that to each two parts of blueberry soil one part of well-rotted cow manure was added. At first the manured plants appeared, superficially, to be doing better than those not manured, for in the former the production of new leaves and the continued growth of the stem were not interrupted by the potting, while in the plants not manured there was a temporary but definite stoppage of stem growth immediately after the potting. The apparent superiority of growth in the manured plants, above ground, continued for about three weeks. Below ground, however, the roots of the two cultures showed directly opposite results. In the plants without manure, new root growth began a few days after potting. At the end of three weeks the development of an extensive root system was well under way and the plants were

ready for a period of vigorous stem growth. In the manured plants, however, either no new root growth took place or only a slight amount. The old rootlets turned brown and appeared to be dead or dying. At the end of five weeks the growth of the tops was very slow. About ten days afterward, on a bright, warm day, the lower leaves on three plants withered, and within a few weeks all six of the manured plants were dead.

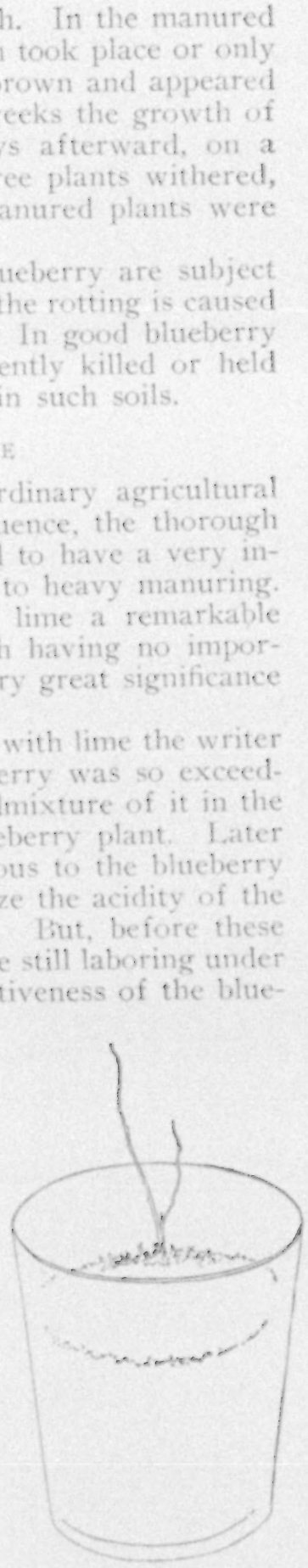
Except in acid soils the roots of the blueberry are subject to decay, their whole action indicating that the rotting is caused or aided by injurious bacteria and fungi. In good blueberry soils, however, these organisms are apparently killed or held in check by the acids that exist naturally in such soils.

EXPERIMENTS WITH LIME

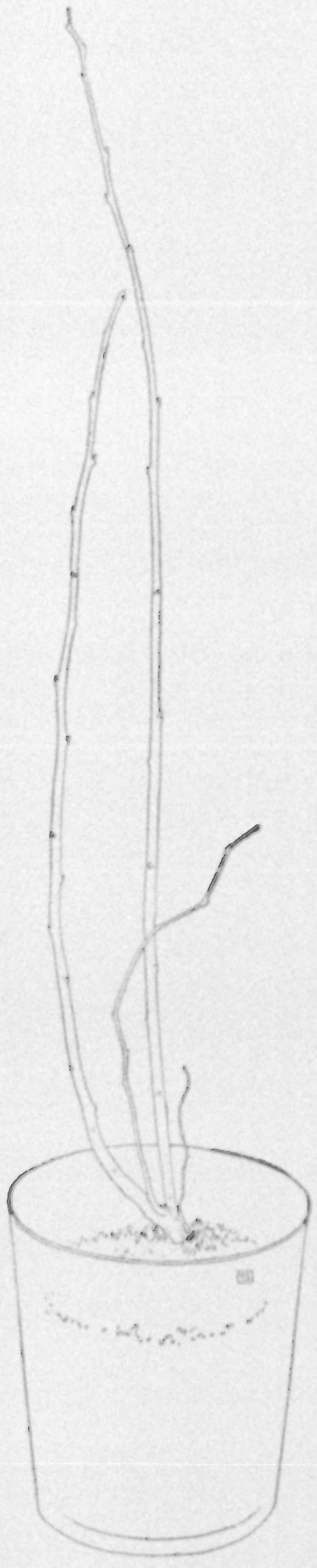
Although the application of lime to ordinary agricultural crops has usually a marked beneficial influence, the thorough liming of a good blueberry soil was found to have a very injurious effect on blueberry plants, similar to heavy manuring. In the course of these experiments with lime a remarkable phenomenon was produced, which, though having no important bearing on blueberry culture, is of very great significance to agriculture in general.

From some imperfect early experiments with lime the writer had erroneously concluded that the blueberry was so exceedingly sensitive to lime that the slightest admixture of it in the soil would be immediately fatal to a blueberry plant. Later experiments showed that lime was injurious to the blueberry only when in sufficient amount to neutralize the acidity of the soil, one per cent usually being adequate. But, before these later experiments had been made, and while still laboring under an erroneous conception of the supersensitiveness of the blueberry plant to lime, the writer, desiring to produce fresh examples of this phenomenon, placed a very small quantity—a few milligrams—of air-slaked lime on the surface of the soil in each of three 2-inch pots containing a small blueberry plant. No effect was produced, either at first or for several weeks.

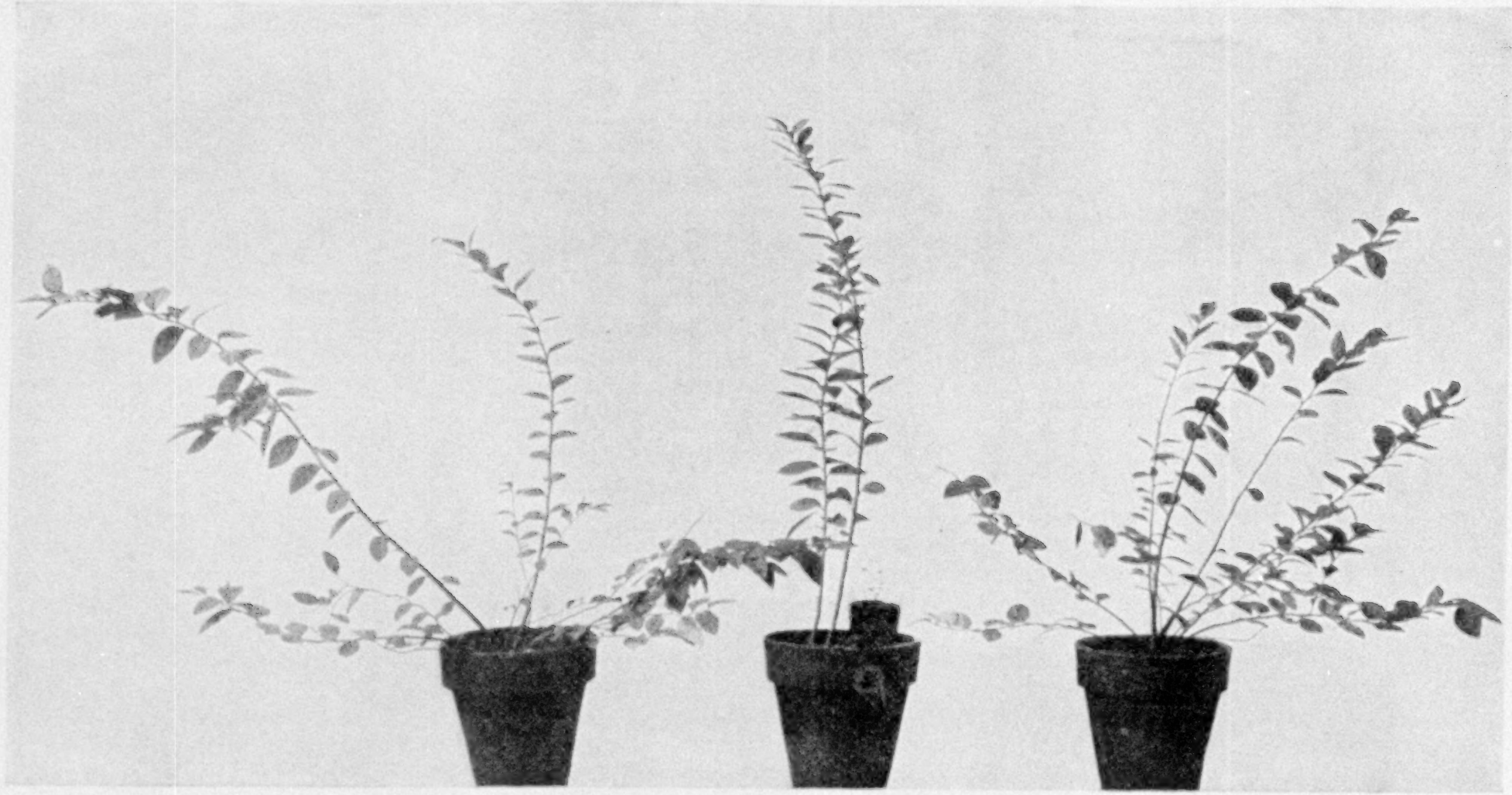
A large surface application of carbonate of lime was then made to the same three plants, a gram to each pot, and the lime was washed down with water. The expected collapse did not occur. The limed plants continued to grow as luxuriantly as their unlimed neighbors. The conclusion was reached that the reason why the growth of the plants had not been affected was because the lime had not penetrated sufficiently into the soil. Another and more drastic experiment was therefore determined upon.



Blueberry seedling in rich garden soil. (One-half natural size.)



Blueberry seedling in peat mixture. (One-half natural size.)



LARGE ONE-YEAR-OLD SEEDLINGS OF THE SWAMP BLUEBERRY

All three plants, grown in pure upland peat, are over 24 inches high, the one at the left 27 inches. The middle plant has been pruned. Standing on the middle pot is a small glass pot containing a seedling of the same age as the others, but grown in a rich garden soil. (One-eighth natural size.)

Six seedling blueberry plants in 4-inch pots containing a good acid blueberry soil were set apart from their fellows and watered exclusively with ordinary lime-water. The applications were of such an amount that the soil in the pot was thoroughly wetted each time, and usually a small excess quantity ran through the hole in the bottom of the pot.

For more than seven months these pots received no other water than lime-water. During this period the plants continued to grow in a normal manner, their average height increasing from 4½ to 14 inches. The lime appeared to have no deterrent effect whatever on the growth of the plants. An analysis of the soil in one of the pots showed that it contained over 8 per cent of lime, or the equivalent of an application of 25 tons per acre, an enormously excessive amount from the standpoint of agricultural usage.

The blueberry plants ought to have been dead long before. As a matter of fact they were making excellent growth. A careful examination of the contents of one of the pots was then made. The surface of the soil was found to be covered with a hard gray crust of lime. Immediately underneath for a depth of about half an inch the soil was black and contained no live blueberry roots. Beneath this the peaty soil was dark brown and filled with growing, healthy roots. The lime appeared to have penetrated only into the superficial portions of the soil. A chemical test confirmed this, showing that the black, rootless upper layer was densely impregnated with lime, while the brown, peaty portion containing the growing roots still gave the acid reaction that was characteristic of the whole potful of soil before the lime-water applications began.

Since all the water that the limeless, root-bearing portion of the soil had received during the preceding seven months had come from the lime-water applications, it was evident that the lime contained in the lime-water had been deposited in the upper half inch of the soil. The following laboratory experiment confirmed this: A 2-inch glass pot was filled to the depth of three-fourths of an inch with the acid upland peat used in growing blueberries. The peat was slightly moist and of rather fine texture, having been rubbed through an eighth-inch sieve. Then ordinary lime-water reddened by the addition of phenolphthalein—a substance giving a delicate color test for alkalies such as lime—was poured upon the soil. The excess water that filtered through the soil and came out of the hole in the bottom of the pot was wholly devoid of red color and, when submitted to a further chemical test, showed not a trace of lime. The precipitation of the lime by the soil had been not only complete but practically instantaneous. Only 15 seconds had elapsed between the time when the lime-water was added to the soil and the time when the liquid, entirely free from lime, began to drop from the pot.

This experiment has a very important bearing on the method of applying lime to acid soils in ordinary agricultural practice. A surface application of lime would have no appreciable effect in neutralizing the acidity of a soil unless the soil were so sandy, or gravelly, or otherwise open that the rain-water containing the dissolved lime could run down through it practically without obstruction. A surface dressing of lime would have little effect in neutralizing the acidity of an old meadow or pasture. To secure full action of the lime, as now generally recognized in the best agricultural practice, requires its intimate mixing with the soil, such as is accomplished by thorough harrowing, especially after putting the lime beneath the surface with a drill.

WHERE TO LOOK FOR BLUEBERRIES

The favorite type of acid soil for the swamp blueberry is peat. The peat chiefly used in the experiments was not, however, a bog peat, but an upland peat formed of a half decomposed mass of mixed leaves of oak and laurel (*Kalmia latifolia*). This accumulates for years

in thickets of laurel, if fire is kept out, making a layer often 2 to 6 inches in thickness, the lower portions matted together by the fine, interlacing surface roots of the oak trees and laurel bushes.

When the leaves of trees are piled together and left to rot they gradually change, in from two to five years, from their initial state of pronounced acidity and brown color to a black, mellow, non-acid mold in which all traces of leaf structure have disappeared. Through a similar but more rapid process of decomposition pass the fallen leaves of a forest when underlain by a soil which is rich in lime or for any other reason has an alkaline reaction. Such a black mold occurs in the rich woods in which trillium, spring beauty, blood-root, and erythronium delight to grow. This soil is non-acid and fertile, and ordinary agricultural plants grow luxuriantly in it.

When, however, a forest is underlain by a sandy or granitic soil, in which there is not sufficient lime or equivalent substance to neutralize promptly the acidity of the decaying leaves, the normal progress of decomposition lags. Apparently the micro-organisms which cause the rotting of the leaves are not able to do their work so efficiently while the leaves remain acid, and when the next year's leaf-fall occurs they are deluged with new leachings of acidity. A permanently acid condition of the leaf litter is thus established, such as prevails in various types of forest. Such acid lands have a flora of their own—such plants as trailing arbutus, laurel, the azaleas, wintergreen, blueberries, huckleberries, the purple lady's slipper, and many others.

Thus it is that the swamp blueberry occurs not only on sphagnum-cushioned hummocks of peat in bogs, but on sandy uplands in upland leaf peat. When found in such places the plant commonly bears another name—the highbush blueberry. The essential feature of similarity in the two situations is their acidity and wherever the plant goes it follows an acid soil.

The geographic distribution of blueberries, huckleberries, and their relatives indicates their adherence to naturally acid soils. They occur in abundance from Maine to Florida in the sandy coastal plain, the prevailingly acid character of which is now well known through the conclusive experiments of Dr. H. J. Wheeler, of the Rhode Island Agricultural Experiment Station. They occur generally through the cool, humid hill-lands of New England, the acidity of which is notorious. They occur in sandy pine barrens and peat bogs throughout the eastern United States, both of which are acid. They are absent, on the contrary, from limestone soils, rich bottom lands, and rich woods where the soils are neutral or alkaline. In the lower elevations of the whole subarid West, where acid soils are almost unknown, these plants do not occur. Within reach of the fogs and heavy rainfall of the Pacific coast, or on the higher mountains of the interior, where conditions favor the development of acid soils, blueberries occur again in characteristic abundance.

CULTIVATING BLUEBERRIES IS EVIDENTLY VERY PROFITABLE

The experiments in field culture, as distinguished from the experiments with potted plants, have been in progress for but a short time, and only after the lapse of several years can definite statistics of yield, cost, and profits be given. The preliminary announcement of these experiments, however, has brought out one very interesting bit of information, namely, that a 5-acre bog near Elkhart, Indiana, set with wild blueberry bushes about 20 years ago has for many years produced large crops of berries, the area yielding in some years a clear profit of more than $100 an acre. The berries are sold at 15 to 18 cents a quart, and 5 cents a quart is paid for picking.

This is the only instance known to the writer in which the cultivation of the blueberry has heretofore been attempted on an acreage scale. Without further experience it is impossible to say whether this yield is larger or smaller than may

BLUEBERRIES GROWN IN A GREENHOUSE (NATURAL SIZE)

reasonably be expected of a blueberry area under good management. It is of some significance, however, that according to the reported yield the bushes in the Elkhart bog, which are set 6 by 6 feet, average about a quart of berries each in a good year, while in almost any good blueberry pasture in New England exceptional wild bushes may be found that produce from 4 to 6 quarts of berries each. It is to the selection and propagation of such productive plants with large, attractive, and fine-flavored berries that experimental culture should devote itself. The propagation of bushes with berries over half an inch in diameter is already actually in progress.

The only fruit the culture of which bears any resemblance to that of the blueberry is the cranberry. The two plants are closely related botanically; they both require an acid soil, and they both have a mycorhizal fungus on their roots, essential apparently to their successful culture. Cranberry-growing is a highly specialized and profitable industry, the development of which has required nearly a century of experimentation. It is only within the last few years that any really scientific attention has been paid to cranberry culture, the development of the industry having been accomplished by commercial growers. Progress in learning to handle the plant has therefore been slow and costly, but highly practical, and cranberry culture has much of experience to offer, by way of suggestion, to blueberry culture.

In preparing a bog for cranberry-growing the water level is lowered at least a foot below the surface by ditching; then a few inches of the top soil

are removed by a process known as "turfing," which carries away all the native vegetation, and the naked peat is smoothed and covered with a few inches of clean sand. In this the cranberry plants are set. The provision of ponds or reservoirs to permit the rapid flooding of the bog completes the initial equipment. Such treatment of land is expensive when well done, costing perhaps $400 an acre. But a first-class cranberry bog in full bearing is often valued at $1,000 an acre, and each acre may be expected to produce a gross revenue of $300 per year, sometimes twice that amount.

A bog thus prepared promises to be an ideal situation for the swamp blueberry. Whether the profits would warrant the expenditure of so much money remains to be seen; but the expense may be reduced to a minimum by cutting out the turfing, sanding, and reservoir building, the blueberry plants being merely set in holes dug in the bog, after drainage, at intervals of about 8 feet each way.

Another sort of situation that gives experimental promise is a sandy, well-drained, but permanently moist upland possessing a distinctly acid soil. The plants should be set in trenches or separate holes filled with peat to the depth of about a foot. The surface should be well mulched with leaves or clean sand, and a deep mulch of leaves, preferably oak, should be added each year. The excavations should provide ample space for new growth of the roots, not less than a foot each way from the surface of the old root-ball.

The peat used may be taken from the surface of a bog containing plants of the heather or blueberry family, or it may be an upland peat, such as that described on page 144. In either case it should be gathered, piled, and rotted for several months before using.

The soil in which the holes or trenches are made should be such as will give good drainage, the ideal condition of the peat about the roots of the plant during the growing season being one of continued moisture, but with all the free water draining away readily so that thorough aëration of the mass of peat is assured.

To secure a stock of blueberry plants, the simplest method is to transplant wild bushes in early spring, before the buds have begun to push. The roots usually lie within the upper 6 inches of the soil. A disk of this root and soil mat as large as practicable should be taken up with the bush.

If the experimenter has a greenhouse at his disposal he can raise seedlings, which will be ready for field-planting in the spring of their second year.

Seedling bushes are unsatisfactory in one respect. They are not exactly like the parent. The seedlings from a large-berried bush do not all bear large berries. Selected forms of special merit have been propagated by budding and by grafting, just as our highly developed varieties of apples are perpetuated; but in the blueberry the stock is continually sending up new shoots from points below the graft. As blueberry culture develops it will undoubtedly become the practice to propagate the best varieties by layering or by cuttings, as has already been done, for by these methods the whole plant body, including the roots, is of the variety desired, and alien shoots can never be produced.

BLUEBERRY BUSHES LIVE MANY YEARS

As to the time required for a blueberry seedling or cutting to come into profitable bearing, experience cannot yet give a definite answer. They should bear a few berries the second and third years. It is believed they will bear profitable crops, under proper culture, in 5 to 10 years. They ought to remain in bearing for a long time. In some instances wild bushes undoubtedly live, in favorable situations, for 50 to 100 years. They are enabled to reach such an age by continual rejuvenescence through their habit of sending up new stems from the root to replace old and dying ones. Those who are curious to know how large an old blueberry bush may become should read Thoreau's descrip-

tion of one in his Winter Journal, under date of December 24, 1859.*

One interesting feature of blueberry culture is the cheapness of the lands on which they thrive best. Bog lands and sandy lands well suited to the blueberry can be bought in many parts of New England for $1 to $5 an acre, and this because the very reason that makes them good for blueberries—their acidity—has made them almost worthless for ordinary agricultural purposes.

Some reader will ask, "Do you advise me to go into blueberry culture?" My reply is, the industry is so new and so many unforeseen difficulties are bound to arise that, until the details of successful field management have been worked out, blueberry-growing is not recommended as an industry to any one who cannot afford to lose both the time and the money he may put into it. On the other hand, if one does succeed in carrying the thing through successfully, he may expect good returns from his venture, for the Elkhart farmer, while apologizing for his poor blueberry crop of 1910, which was "almost a total failure" on account of the late spring freezes, says nevertheless that he got 65 16-quart crates of berries, which he sold at an average price of $2.75 a crate—an item of $178.75 from an otherwise useless 5-acre bog.

I remarked to a friend that blueberry culture promised to be comparable in many respects with cranberry culture. He quite outran the idea that was in my mind by replying, "Why, it has the cranberry beaten. You can't use cranberries without buying a turkey to eat with them."

* December 24, 1859. . . . . I measure the blueberry bush on Fairhaven Pond Island. The five stems are united at the ground, so as to make one round and solid trunk thirty-one inches in circumference, but probably they have grown together there, for they become separate at about six inches above. They may have sprung from different seeds of one berry. At three feet from the ground they measure eleven, eleven, eleven and one-half, eight, and six and one-half or on an average nine and one-half inches. I climbed up and found a comfortable seat, with my feet four feet from the ground. There was room for three or four more there, but unfortunately this was not the season for berries. There were several other clumps of large ones in the neighborhood. One clump close by the former contained twenty-three stems within a diameter of three feet, and their average diameter at three feet from the ground was about two inches. These had not been cut because they stood on this small island which has little wood beside, and therefore had grown thus large. . . .

The stems rise up in a winding and zigzag manner, one sometimes resting in the forks of its neighbor. Judging from those whose rings I have counted, the largest of those stems must be about sixty years old.—BLAKE, H. G. O. (editor). Winter: From the Journal of Henry D. Thoreau, 16-17. 1888.

THE PANAMA CANAL*

By Colonel George W. Goethals, Chief Engineer of the Panama Canal

IT is not possible in the time at our disposal to enter upon a description of the explorations and investigations which were made of various routes proposed for a canal joining the two oceans, nor can an account be taken of the considerations which resulted in the United States finally adopting the Panama route. Suffice it to say that under the Spooner Act, approved June 28, 1902, the President of the United States secured the necessary concession from the Republic of Panama, purchased the rights and property of the New French Canal Company, and undertook the construction of the canal on May 4, 1904.

The Isthmus of Panama runs nearly east and west, and the canal traverses it from Colon on the north to Panama on the south, in a general direction from northwest to southeast, the Pacific terminus being 22 miles east of the Atlantic entrance.

TORRENTIAL FLOODS OF THE CHAGRES RIVER

The greatest difficulty of the Panama route is the control or disposition of the Chagres River and its tributaries. The Chagres River rises in the San Blas Mountains and drains a basin of 1,320 square miles, about half of which is above the mouth of the Obispo River. Its course is generally parallel to the Caribbean coast line so far as the mouth of the Obispo, where it turns almost at right angles to the westward, pursuing this general course to Tabernilla, whence it traverses a tortuous channel in a general northwesterly direction and enters the Caribbean Sea to the west of Limon Bay.

The general elevation of the valley is but little above sea-level to Bohio, where the low-water surface of the Chagres is one foot above mean tide. At the mouth of the Obispo, 13 miles from Bohio, the low-water surface is 48 feet above, and at Alhajuela, 11 miles farther, it is 95 feet above the same datum. Above Bohio the Chagres Valley is undulating, the hills becoming higher and steeper as the river is ascended, causing very rapid run-off of the rains, amounting to 100 inches and over in eight or nine months, the average duration of the wet season.

The maximum observed rainfall is 5.86 inches in one hour; the greatest recorded change in the river at Gamboa is a rise of 25.6 feet in 24 hours. Its discharge at the beginning of the rise was 8,200 cubic feet per second, increasing to 90,000 cubic feet per second at the peak of the flood. The excessive rainfall and precipitous character of the hills enclosing the valley make it a torrential stream. The bars formed during floods differ materially, and are of sand, gravel, pebbles, and rounded stones three inches to six inches in diameter. The sand and clay deposits are useful in giving suitable material for the impervious portion of the dams, while the gravel beds furnish ballast for the railroad and for other purposes.

The Chagres River has 26 tributaries between Bas Obispo and Gatun, the largest of which are the Gatun and Trinidad rivers, the former entering from the east with a drainage basin of about 160 square miles, and the latter from the west, draining an area of about 390 square miles. Each rises in the same character of country as the Chagres, and though with smaller drainage areas, they are of the same torrential character and must be reckoned with in the general question of the control of the Chagres and its tributaries.

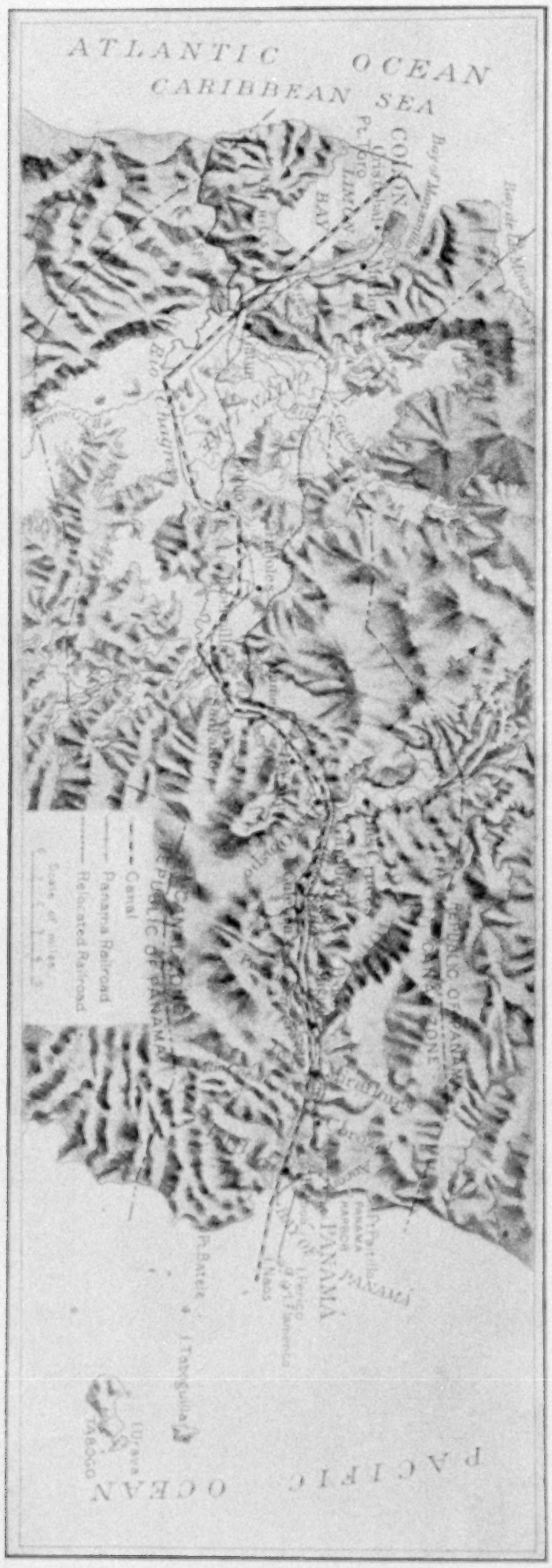
Various methods for the disposition or control of the Chagres have received consideration. The first French com-

* An address to the National Geographic Society, February 10, 1911.

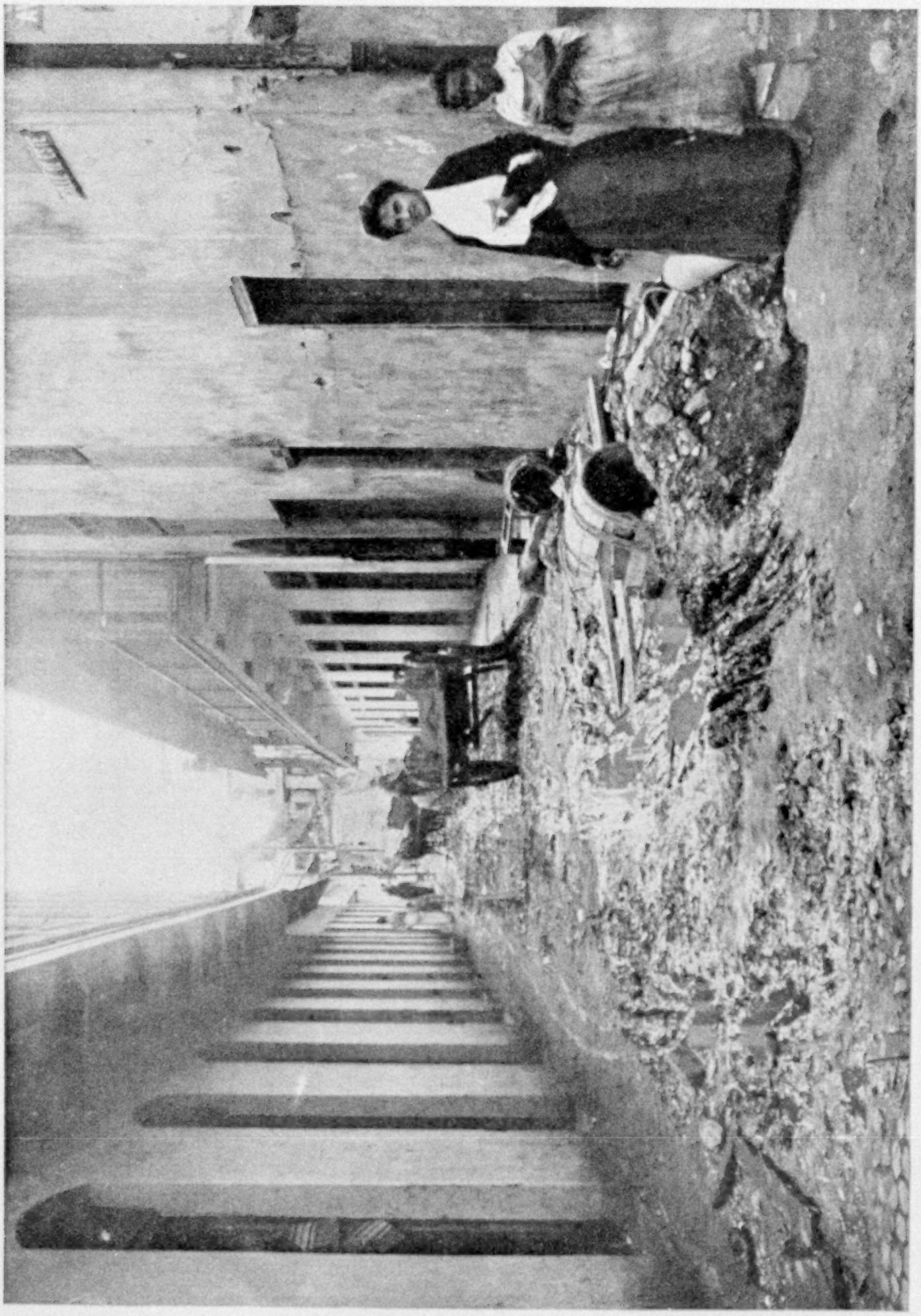
pany, in its attempt to cut a sea-level canal, found it necessary to provide diversion channels to care for the water of the rivers. The New Panama Canal Company adopted the plan of a dam across the river valley at Bohio, creating a lake above this point and discharging the flood waters to the level below by means of a spillway in the adjacent hills. The canal which the President was authorized to construct by the provisions of the Spooner Act was the lock type recommended by the first Isthmian Canal Commission in its report submitted November 16, 1901. This plan also provided a lake for controlling the Chagres by a dam at Bohio, following along the plans of the New Panama Canal Company, thereby utilizing to the fullest extent the work already accomplished.

Early in the progress of the work the construction of a sea-level canal was agitated; this is undoubtedly the ideal canal. It took such a hold on the public mind that, in consideration of the international importance of the work, the President convened a Board of Consulting Engineers to consider and report upon the type of canal which should be adopted. This Board consisted of 13 members—five representatives of European countries and eight Americans—and assembled in Washington in June, 1905. The minority of this Board—five in number—reported in favor of the lock type for the reasons that such a canal would provide greater safety for ships and less danger of interruption to traffic by reason of its wider, straighter, and deeper channels, as well as quicker passage for large ships; the other considerations were that such a canal could be built in less time and for less money.

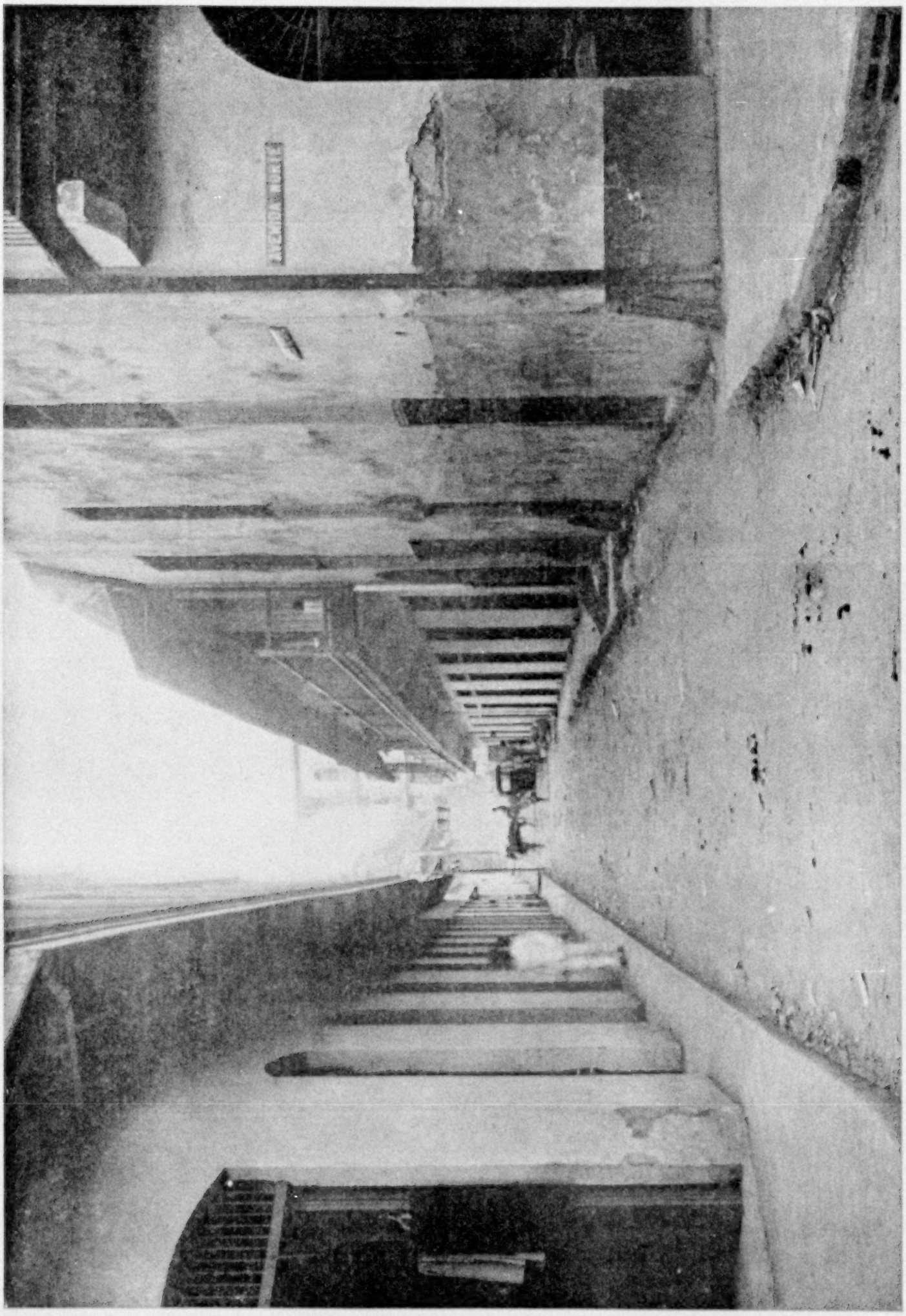
In forwarding the report of this Board to Congress, on February 19, 1906, the President stated: "The law now on our statute books seems to contemplate a lock canal. In my judgment a lock canal as herein recommended is advisable." On June 29, 1906, the Congress authorized the construction of the lock type of canal, in accordance with the general plans of the minority of the Board, and



MAP OF THE CANAL ZONE



A STREET IN THE CITY OF PANAMA AS IT APPEARED WHEN THE UNITED STATES OBTAINED CONTROL OF THE CANAL



THE SAME STREET REPAIRED BY THE AMERICAN ADMINISTRATION

All the streets of Panama and Colon have been renovated in a similar manner. Many miles of macadamized roads have also been built in outlying districts

THE CUSTOMARY LABORER'S MESS, BEFORE AMERICAN CONTROL

the work has since been carried on along these lines.

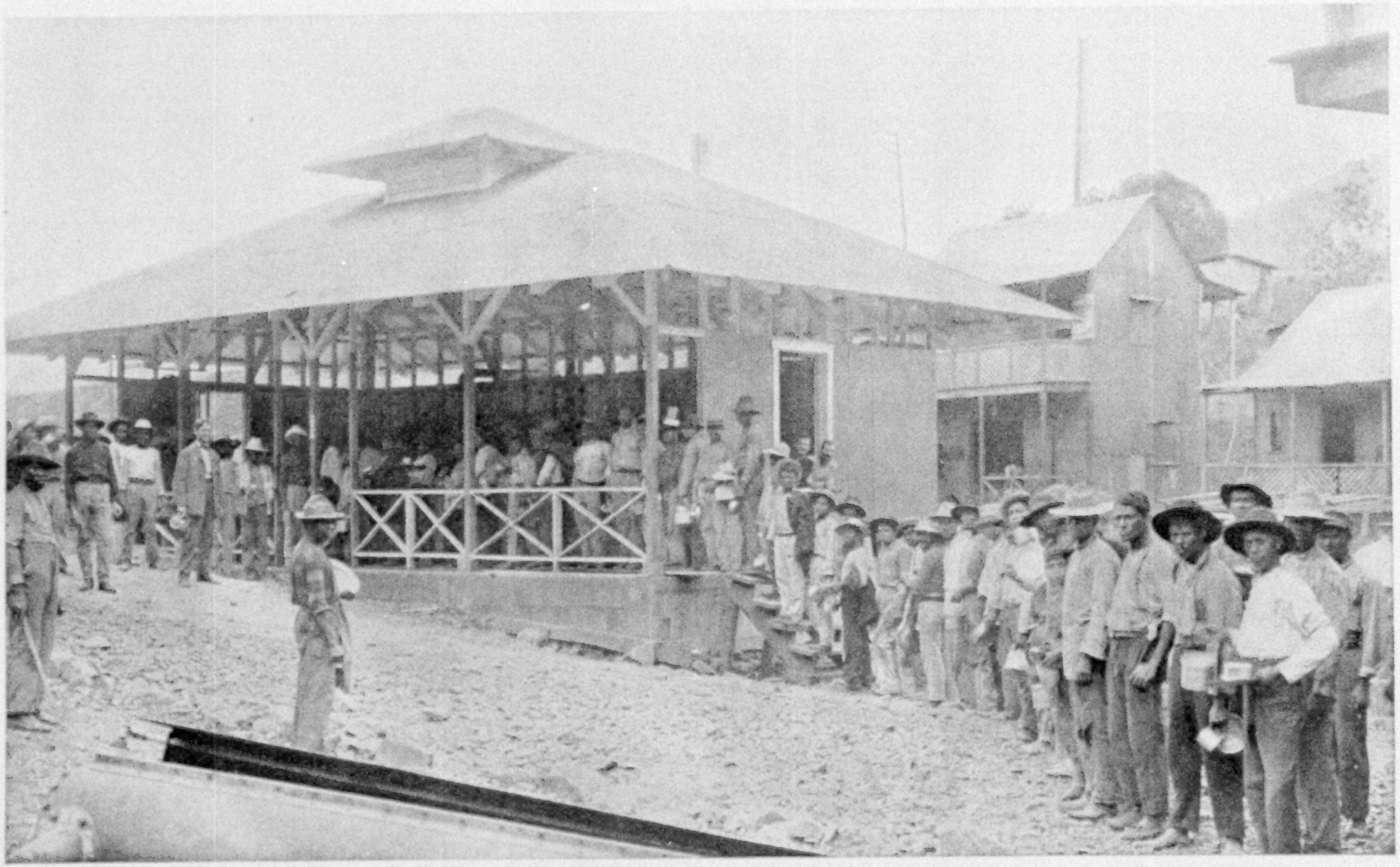
This conclusion was not generally accepted as satisfactory; the plan was again vigorously attacked after the settlement and slip in a part of one of the toes of the Gatun Dam in the latter part of 1908, and the "Battle of the Levels" continued well into 1909, notwithstanding the fact that the then President-elect, with a party of eminent engineers, after a personal inspection of the work advocated no change.

WISDOM OF CHOICE OF LOCK CANAL NOW GENERALLY ACKNOWLEDGED

Since then, as the work has advanced, the wisdom of the choice is clearly shown and there is no doubt as to the ultimate success of the project. Developments within the last year in the form of slides have brought more prominently to the front the excellence of the judgment which accepted the minority plan in lieu of the sea-level plan as advocated by the majority, and show more clearly the greater difficulties that would be encountered in an attempt to construct a sea-level canal.

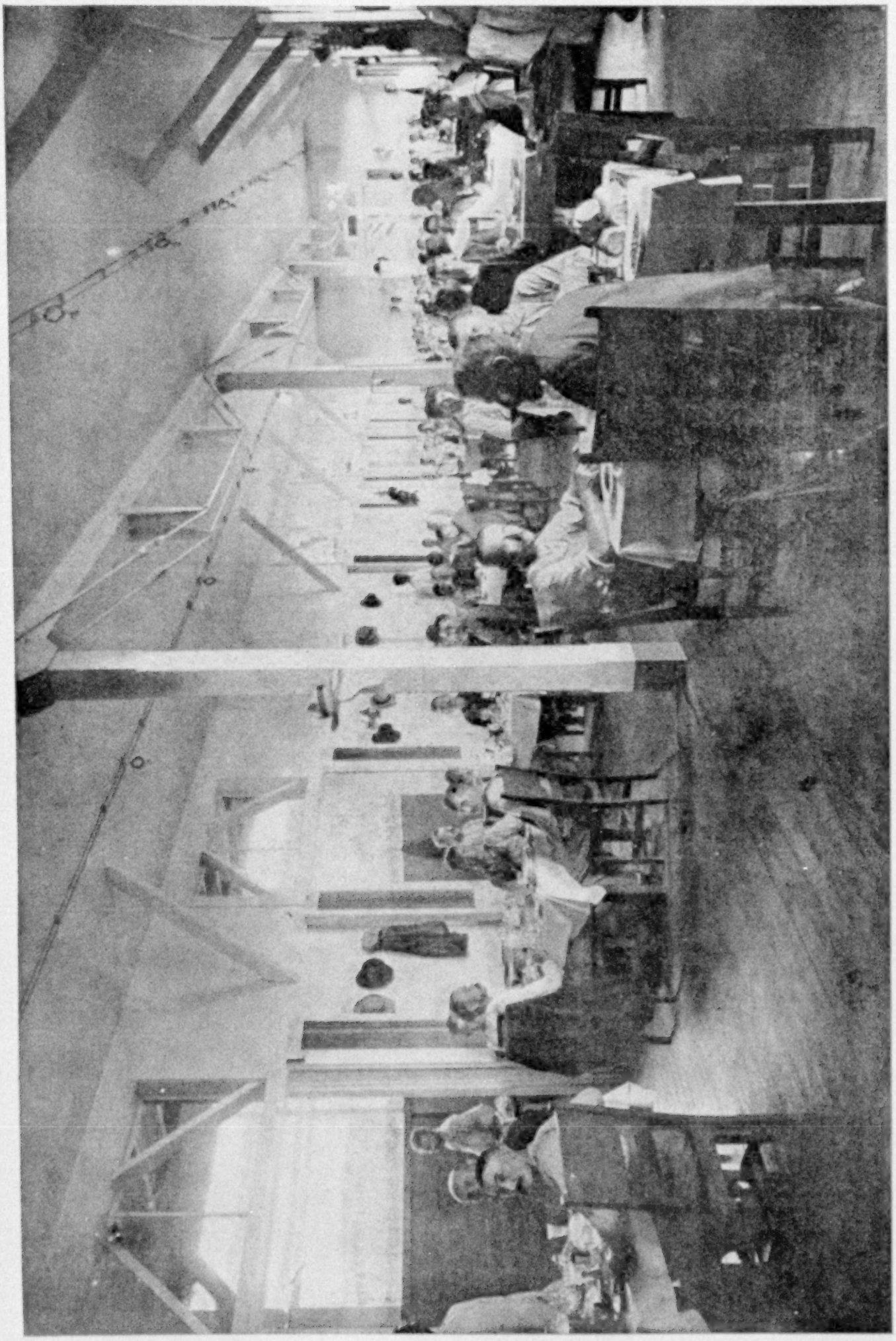
An English scientist, who has kept in close touch with the work since the Americans took charge, and who at first was skeptical as to the Gatun Dam, said, after a recent visit, that he was converted to the present plan because it is not a dam at all that is building, but a veritable hill. He also thought that the expressed opinion of the Board of Consulting Engineers with reference to the Gatun Dam, namely, "that no such vast and doubtful experiment should be indulged in," was now applicable to Culebra Cut. There are probably some who still believe a wrong choice was made, but a visit to the Isthmus is a sure cure for such cases, provided always that they are open to conviction.

In the present plan the control of the Chagres is also effected by a lake, but greater in extent, because the dam is located at Gatun instead of Bohio. This solution was first proposed by Godin de



LABORERS WAITING FOR THE MEAL HOUR AT ONE OF THE MESSES FOR THE "SILVER ROLL"

To avoid the color question, all employees are divided into two classes, those paid in gold, who form the "gold roll," and those paid in silver, the "silver roll." Americans and Europeans belong to the former, and the West Indians and Panamans to the latter. These men can get a meal ticket for 30 cents after they have done one-half day's work. The meal costs the Commission 27.29 cents.



MESS-HALL AT CULEBRA, IN WHICH MEN ARE PERMITTED TO EAT WITHOUT THEIR COATS

White laborers can get meal tickets for 40 cents each. The meal actually costs the Commission 36.84 cents. The net weight of the ration furnished the European laborer is exactly equal to the gross weight of the United States Army garrison ration, and the net weight of the ration furnished the negro laborer is exactly equal to the gross weight of the United States Army field ration.

Lépinay, a French engineer, who, in an exhaustive paper on the subject, prepared for the Congress of Engineers in Paris in 1879, advocated the construction of a lock canal with a dam at Gatun in lieu of a sea-level canal. The reasons which he advanced at that time were to the effect that such a canal could be built for less money, in less time, and with less sacrifice of life.

THE PRINCIPAL FEATURES OF THE CANAL.

The canal which is now building consists of a sea-level entrance channel from the sea through Limon Bay to Gatun, about seven miles long, 500 feet bottom width, and 41 feet deep at mean tide. At Gatun the 85-foot lake level is obtained by a dam across the valley. The lake is confined on the Pacific side by a dam between the hills at Pedro Miguel, 32 miles away. The lake thus formed will have an area of 164 square miles and a channel depth of not less than 45 feet at normal stage.

At Gatun ships will pass from the sea to the lake level, and *vice versa*, by three locks in flight. On the Pacific side there will be one lift of 30 feet at Pedro Miguel to a small lake held at 55 feet above sea level by dams at Miraflores, where two lifts overcome the difference of level to the sea. The channel between the locks on the Pacific side will be 500 feet wide at the bottom and 45 feet deep and below the Miraflores locks the sea-level section, about eight miles in length, will be 500 feet wide at the bottom and 45 feet deep at mean tide. Through the lake the bottom widths are not less than 1,000 feet for about 16 miles, 800 feet for about four miles, 500 feet for about three miles, and through the continental divide, from Bas Obispo to Pedro Miguel, a distance of about nine miles, the bottom width is 300 feet.

The total length of the canal from deep water in the Caribbean, 41-foot depth at mean tide, to deep water in the Pacific, 45-foot depth at mean tide, is practically 50 miles, 15 miles of which are at sea level. The variation in tide on the Atlantic side is 2.5 feet as a maximum, and on the Pacific it is 21.1 feet as a maximum.

Provisions are made to amply protect the entrances of the canal. During the winter months occasional storms occur on the Atlantic side, of such violence that vessels cannot lie with safety in Colon Harbor, and during the progress of such storms entrance and egress from the canal would be unsafe. To overcome this condition, a breakwater will extend out about two miles from Toro Point in a northeasterly direction, which will not only protect the entrance, but will provide a safe harbor. Whether protection on the east side will be ultimately necessary is still an open question.

The Pacific entrance requires no protection from storms, but the set of the silt-bearing current from the east is at right angles to the channel and the silting made constant dredging necessary. To prevent this shoaling a dike is being constructed from the mainland at Balboa to Naos Island, a distance of about four miles; the benefits derived from it are already very marked.

The projected lakes will submerge the tracks of the Panama Railroad for the greater part of its length, and as this road is necessary for construction purposes, and ultimately for the operation and maintenance of the canal, it is being reconstructed throughout, with the exception of a few miles at either end. It was originally intended to pass the new railroad through Culebra Cut on a berm, 10 feet above the water surface, to be left for this purpose during the excavation of the channel through the cut, but the slides and the absolute necessity for keeping open railroad communication between the two ends of the line necessitated a change in the location, and a new line to the east of the cut has been selected.

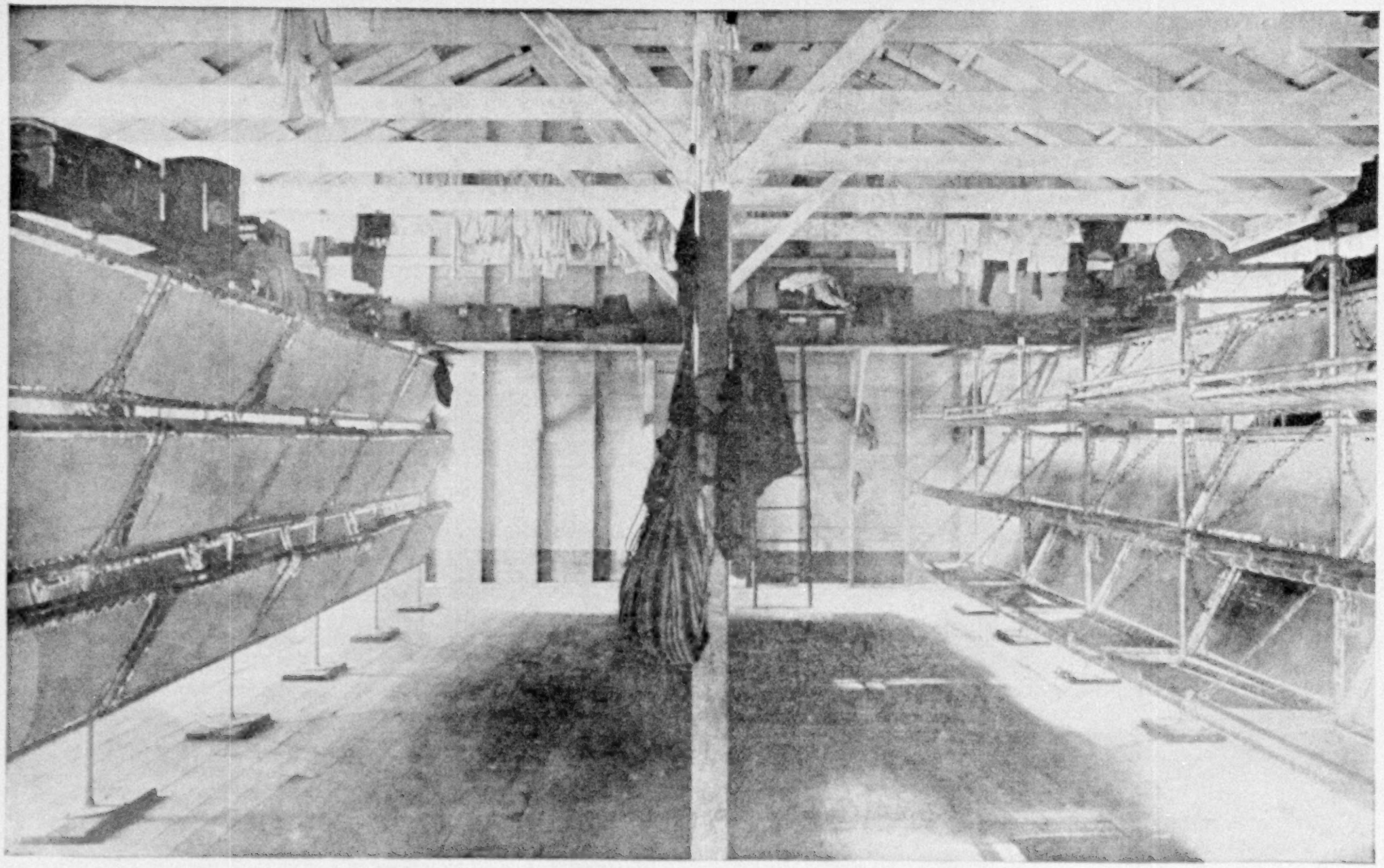
In order to hold its concession the French company continued work on the canal up to the time that the United States assumed control, and after the transfer of rights and property was formally made the excavation was carried

A GROUP OF ITALIAN LABORERS

These men are paid from 16 to 20 cents an hour

SPANISH LABORERS ON THE CANAL.

The popularity of the work on the Isthmus has become so great that it is no longer necessary for the Canal Commission to bring in shiploads of recruits from the West Indies and Europe. Laborers are so attracted by the good pay, fair treatment, and excellent living conditions that more than 2,000 came from Spain and Italy during 1910. Old laborers who had left the work to go to Brazil and South American countries have also been returning to the Isthmus in large numbers, seeking re-employment. There are at present about 35,000 on the rolls of the canal works.



SLEEPING QUARTERS FOR EUROPEAN LABORERS, SHOWING THE THREE ROWS OF "STANDEE" BUNKS

The Commission maintains about 150 houses in which approximately 5,700 European bachelor laborers are quartered

on by the United States with the various tools and appliances then in use.

MAKING THE ISTHMUS HEALTHY

The first two and a half years of American control were given to preparation. All energies were devoted during that time to rid the Isthmus of disease by sanitation, to recruiting and organizing a working force, and providing for it suitable houses, hotels, messes, kitchens, and an adequate food supply; to assembling the plant to do the work; to increasing the capacity of the existing railway system, and to establishing a system of civil government for the Canal Zone, which is a strip of land 10 miles wide (five miles on either side of the center of the canal), extending across the Isthmus.

The work of sanitation included clearing lands, draining and filling pools and swamps for the extermination of the mosquito, the establishment of hospitals for the care of the sick and injured, and the quarantine. In addition, to secure and maintain better health conditions, municipal improvements were undertaken in the cities of Panama and Colon, and the various settlements along the line of canal, such as the construction of reservoirs, with mains and adjuncts, for furnishing wholesome and sufficient water, sewerage, pavements, and a system of roads.

Buildings to the number of 2,009 were constructed, including office buildings, hospitals, hotels, messes, kitchens, shops, storehouses, and living quarters. In addition to this, 1,536 buildings out of a total of 2,200 buildings turned over by the French were remodeled and repaired for use.

Recruiting agencies were established in the United States, Europe, and the West Indies.

AN IMMENSE DEPARTMENT STORE

The Commissary Department of the Panama Railroad Company was enlarged until it is now a great department store supplying to the employees whatever may be necessary for their comfort and convenience. Manufacturing, cold storage, and laundry plants were established and turn out each day about 90 tons of ice, 14,000 loaves of bread, 2,400 rolls, 250 gallons of ice-cream, 1,000 pounds of roasted coffee, and 7,500 pieces of laundry. Four to five refrigerator cars, loaded with meats, vegetables, and such fruits as can be obtained, are sent out on the night freight to distant points, and every morning a supply train of about 16 cars, of which number six to eight are refrigerator cars, leaves Cristobal at 4.30 to distribute food-stuffs and laundry to the local commissaries along the line, where the employees make their purchases and where the hotels, messes, and kitchens secure their supplies for the day.

The construction plant, consisting of steam shovels, locomotives, cars, unloaders, spreaders, track-shifters, pile-drivers, cranes, dredges, steamboats, tugs, and barges, was purchased for the most part "knocked down," and shops for their erection and repair were constructed and enlarged. Some of the machinery was built from parts manufactured in the shops. The distance from the home market, with attendant vexatious delays in securing parts and material and the necessity for keeping the construction plant in the most efficient condition for economical operation, made it imperative that the shops be equipped to meet every possible contingency.

The capacity of the Panama Railroad, over a large part of which the spoil from Culebra Cut must be handled, was increased by double tracking it throughout, except from Cristobal to Gatun and from Culebra to Paraiso. Yards were enlarged and connections made to areas available for dumping grounds.

Laws were framed, and civil government was established with its necessary adjuncts of courts, police force, fire companies, customs and revenue service, post-offices, public works, and treasury.

A purchasing department was organized in the United States for the obtainment of supplies of all kinds and descriptions. Upon arrival on the Isthmus,

A TYPICAL LABOR TRAIN

Locomotive engineers are paid from $180 to $210 a month in United States currency; locomotive firemen from $50 to $60 a month, and common laborers from 10 cents to 20 cents an hour

the supplies are shipped to the various subdivisions of the canal-work for which they were purchased, or they are placed in storehouses along the line for issue when required.

It was only after these various yet necessary adjuncts had been provided and the forces for their operation were organized that the principal work in hand—the building of the canal—could be pushed forward with any hope of success, and too much praise cannot be given to those who conceived and established them in a working condition.

The Department of Construction and Engineering is divided into three construction divisions. The Atlantic Division embraces the engineering construction from deep water in the Caribbean Sea to include the Gatun locks and dam; the Central Division extends from Gatun to Pedro Miguel, and the Pacific Division from Pedro Miguel to deep water in the Pacific Ocean.

KEEPING THE FLOODS OUT OF CULEBRA CUT

As already noted, the Americans continued the work in progress by the French in the cut through the continental divide, commonly known as the Culebra Cut, utilizing the French machinery until it could be replaced by more modern appliances. This is the most formidable part of the enterprise on account of the magnitude of the cutting, and also because of the difficulties attending it, due to the excessive rainfall and to the varying character of the materials encountered.

The efficient and economical working of the plant requires that provisions be made for the disposition of the large quantities of water that result from the rains. Whatever water is not carried off by the streams enters the cut, either through direct fall over the excavated area or by seepage into it. Proper drainage of the cut is therefore an ever-existing problem, and two distinct phases are presented, viz:

1. To keep out the water of the surrounding country.

2. To rid the excavated area of the water that collects in it.

A system of diversion channels accomplishes the first, and gravity drains and pumps solve the second. The canal line follows the Obispo River, which drains the area from the divide to the Chagres River. It has four principal tributaries, two from the east, the Masambi and the Sardinilla, and two from the west, the Mandinga and the Comacho. These are cared for by two diversion channels.

On the east side of the cut the Obispo diversion has been constructed almost parallel to the canal and carried through a depression in the hills so as to discharge into the Chagres about one mile above the point at which the canal line crosses the river.

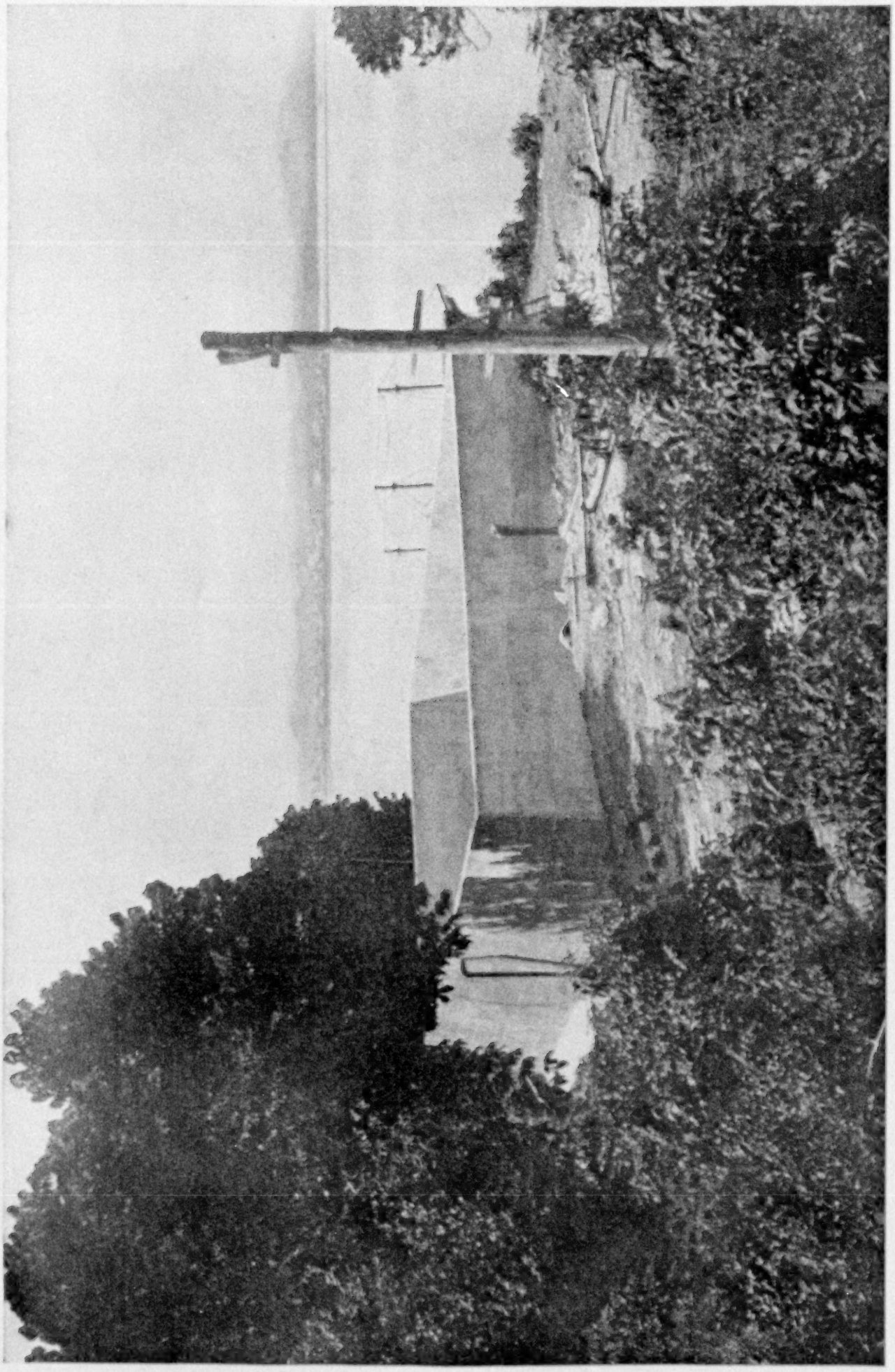
To the west of the cut the Comacho diversion carries the waters from Culebra to the Chagres River through the old channel of the Obispo River. Through a hill between Haut Obispo and Bas Obispo, which sharply deflects the river, the French had built a tunnel for diverting the flood waters, and this forms a part of the new diversion.

The canal follows the Rio Grande on the southern slope of the divide, and its waters are cared for by a diversion channel constructed by the French. They also constructed a dam across the valley, impounding the waters, and the resulting reservoir supplies the settlements from Culebra to and including Panama. During the wet season the diversion channel carries the overflow from the reservoir.

HOW THE SHOVELS WORK

The French so planned the excavation that after the removal of the peak of the divide and lesser summits they could work a number of excavators simultaneously at several points, so that a succession of benches resulted, lying one above the other, each with the natural surface as the point of beginning. By working in the direction of the length of the cut, the face of the bank gives the longest cutting possible, reduces the number of times the excavator must be hauled back, and secures a satisfactory drainage arrangement, since the cutting is carried up grade on either side of the summit.

The Americans have followed this

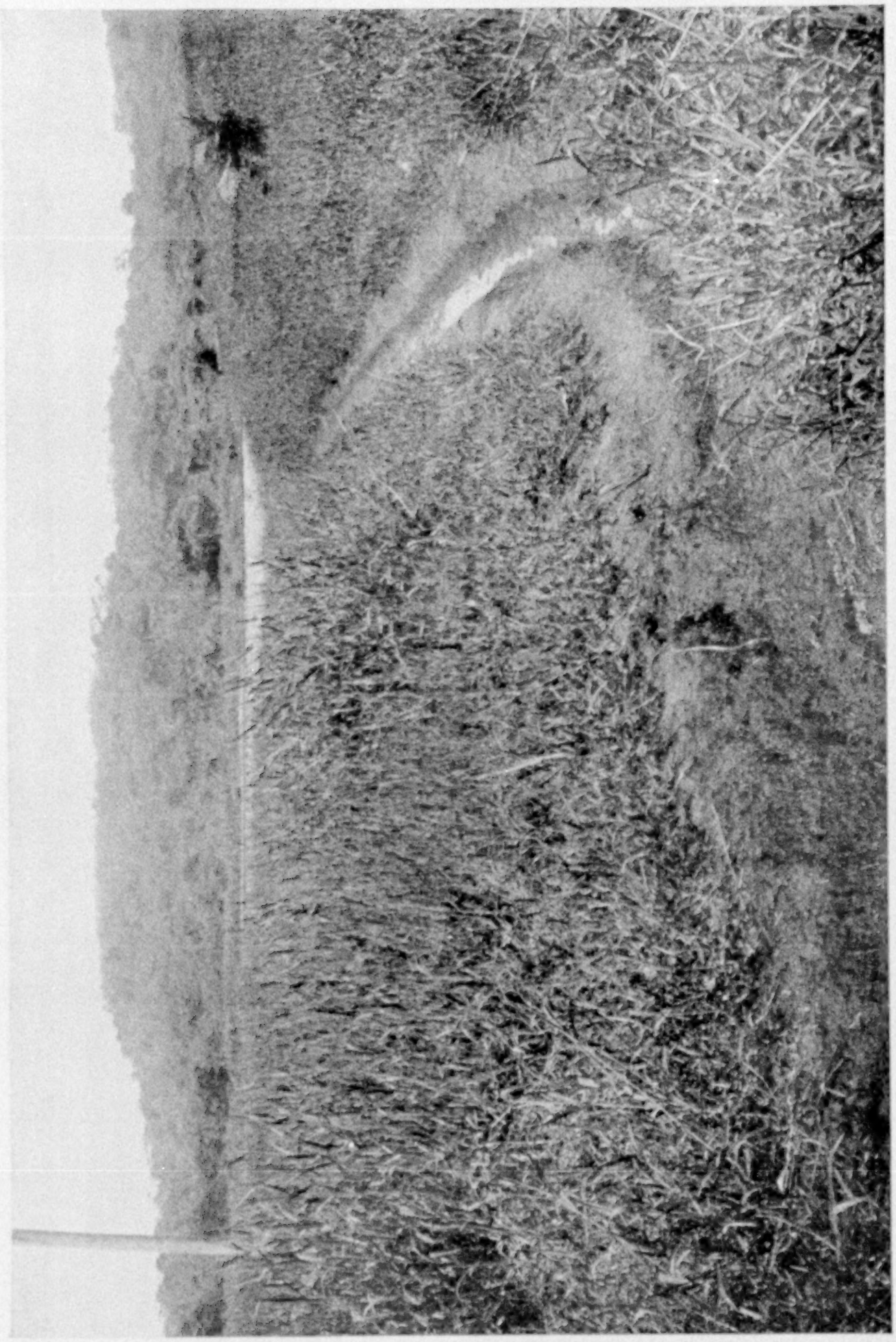


100,000-GALLON REINFORCED CONCRETE RESERVOIR, BUILT ON NAOS ISLAND FOR THE CULEBRA ISLAND QUARANTINE STATION AT A COST OF $5,064: 1910

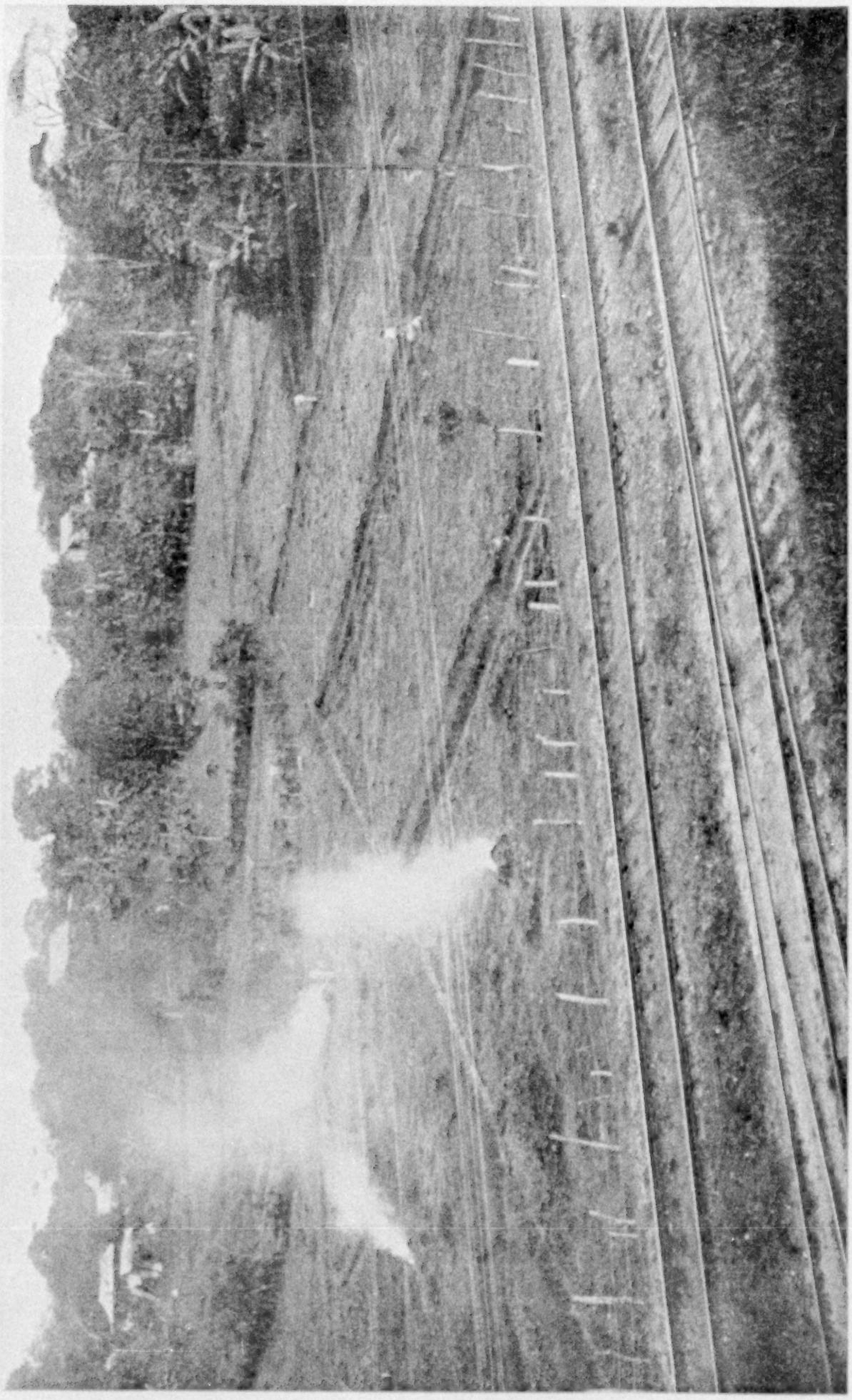
SPRAYING CRUDE OIL IN DITCHES TO EXTERMINATE THE MOSQUITOES

The sanitary department spent $43,000 last year for the purchase of oil and to pay laborers to distribute it

DITCH CLEANED BY HAND LABOR, SHOWING CONDITION TWO MONTHS AFTER CLEANING



CONDITION OF DITCH TWO MONTHS AFTER GRASS-BURNING



SWAMP NO. 4, MOUNT HOPE, NEAR COLON, SHOWING THE ARRANGEMENT OF OPEN-EARTH DRAINS USED FOR SWAMPY AREAS

The sanitary department expended $88,500 in 1910 for maintaining existing ditches and to construct new ones, $127,023.28 in grass and brush cutting, and $72,424 for the removal of night soil and garbage

same method, the only difference being in the character of machinery used. The width of the channel adopted by the French was 74 feet; the present plan is for a channel 300 feet at the bottom, so that the first work undertaken by the Americans was directed to securing the necessary widths for the upper reaches before attempting any increase in depth.

Whatever water entered from rains and seepage was drained from the summit of the cutting by gravity to the Rio Grande on the south and to the Chagres River on the north. As shovels in excess of those required for widening became available, they were put to work to secure increased depth, care being taken to maintain, as far as possible, free, easy, and rapid drainage. Shovels are started at either end and carried towards each other, cutting out at a new summit. These pioneer shovels on the next lower grade make the "pilot cuts," which constitute the new drains and to which water is led by laterals from various parts of the excavated area adjacent. The average grade or slope is about 36 feet per mile. The loading tracks for these shovels are on the level above.

When the "pilot cut" has progressed sufficiently far, its cut or trench becomes the loading track for a second shovel, which is started to widen out the cut already made by the pioneer, and so the work moves forward, the shovels approaching the summit from either direction in echelon.

In 1904 the summit of the excavation was at Gold Hill and at reference 193 above sea level. The summit at present is between Empire and Culebra and is at reference 106 above sea level. The drainage to the south is still by gravity, through the old bed of the Rio Grande to the west of the Pedro Miguel locks. It is expected that before the next wet season the center culvert of the locks will be utilized.

On the north side conditions are now different. The reference of the low-water surface of the Chagres is 43 at the point of its intersection with the center line of the canal. The bottom of the completed canal is at reference 40. A dike separates the cut from the Chagres, but this is overtopped during the high floods. To get rid of the accumulated flood water, 24-inch pipes are laid through the dike, each with a suitable valve, and so arranged that all water above the pipes is carried into the Chagres by gravity after the subsidence of any flood.

Recourse must be had to pumping whatever water remains from the floods below this level, and such as may be collected by drainage from the south; for this purpose a sump has been dug to elevation 32 and pumps installed. It is not possible to estimate the quantity of water that will have to be handled, but three pumps are in place, each capable of discharging 12,000 gallons of water per minute.

VERY TROUBLESOME SLIDES

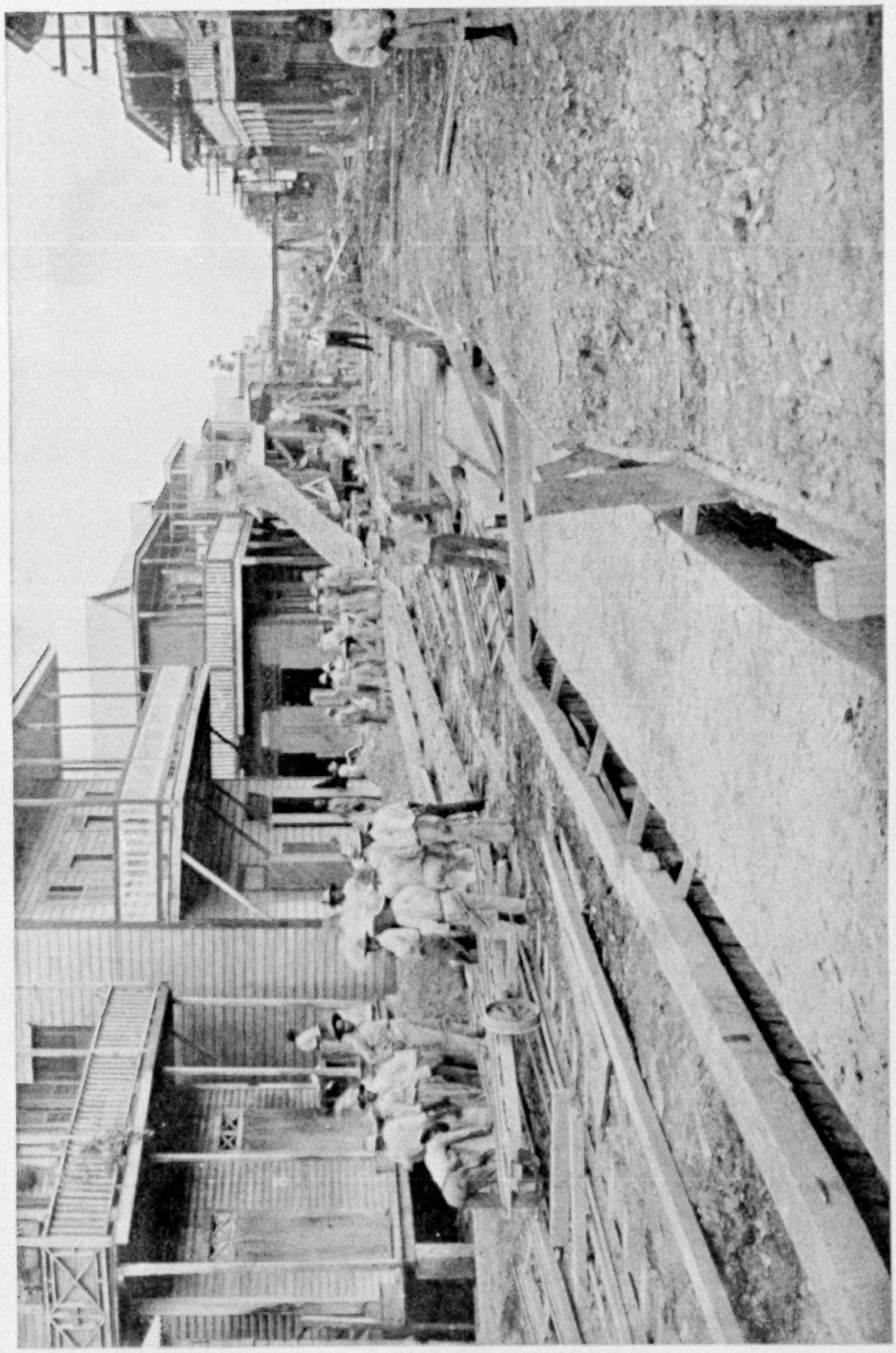
The greatest difficulty encountered in the excavation is due to slides and breaks, which cause large masses of material to slide or move into the excavated area, closing off the drainage, upsetting steam shovels, and tearing up the tracks. The term "slide" is applied to the movement of the overlying clay upon smooth, sloping surfaces of rock or other material harder than the clay.

"Breaks" occur at points where the underlying rock is of poor quality, intersected by vertical seams or seams sloping toward the canal, and which is unable to bear up the superimposed mass. Generally, the upper surface of the broken portion of the bank remains approximately horizontal, settling nearly vertically. The weight of the broken portion forces up and displaces laterally the material lying directly below it in the bottom or on the berms of the canal. As the material thus forced up is taken away the upper part gradually settles and moves toward the axis of the canal until the entire broken portion is removed.

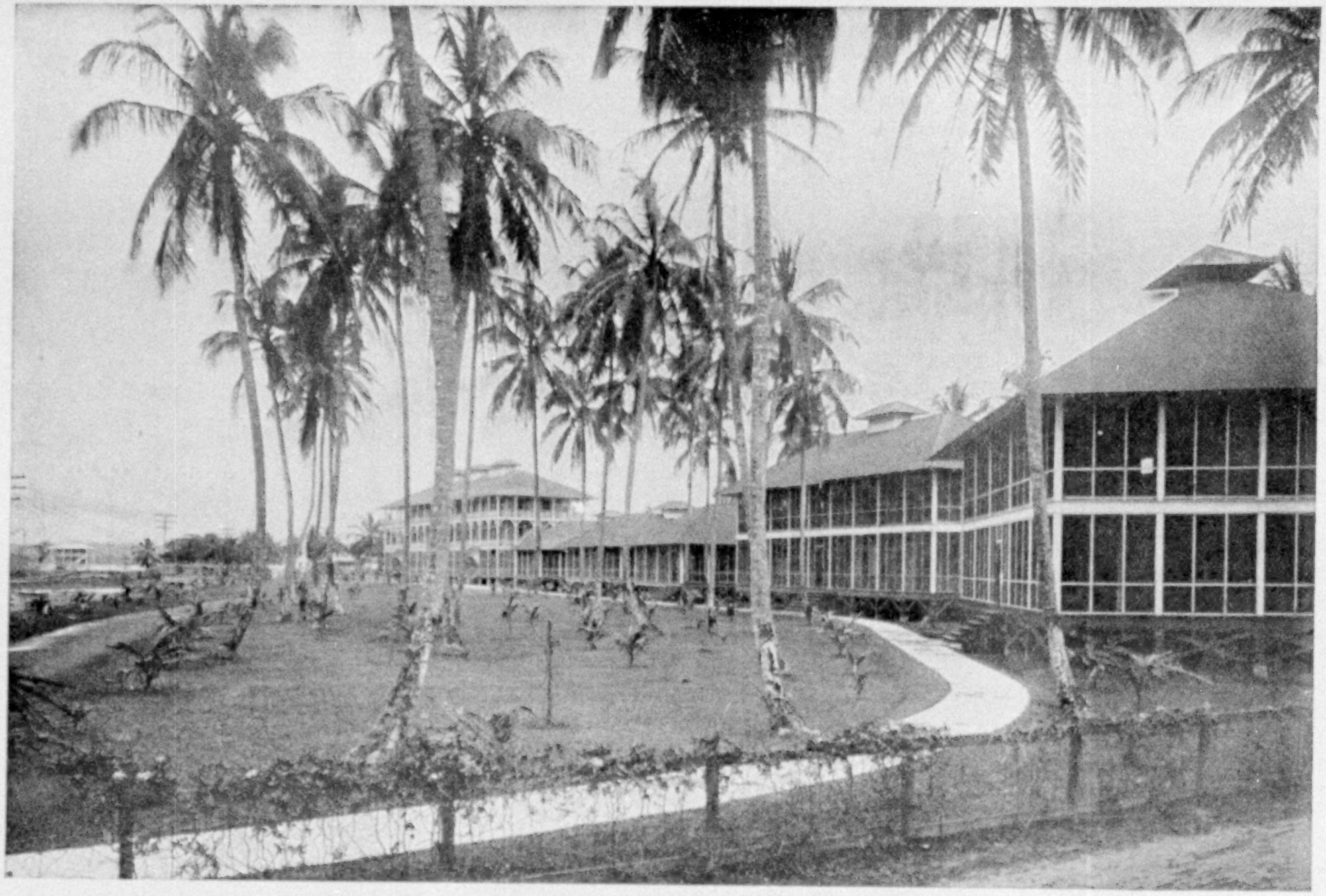
The greatest slide is at Cucaracha, and gave trouble when the French first began cutting, in 1884, and still continues.

METHOD OF EXCAVATION FOR STORM SEWER, "D" STREET, COLON, JULY, 1910

Before the Americans assumed control of the canal there were no sewers and no water system in the Zone. Panama, Colon, and all the towns along the line of the canal have since been provided with excellent water, and sewers for the principal sections have been constructed.



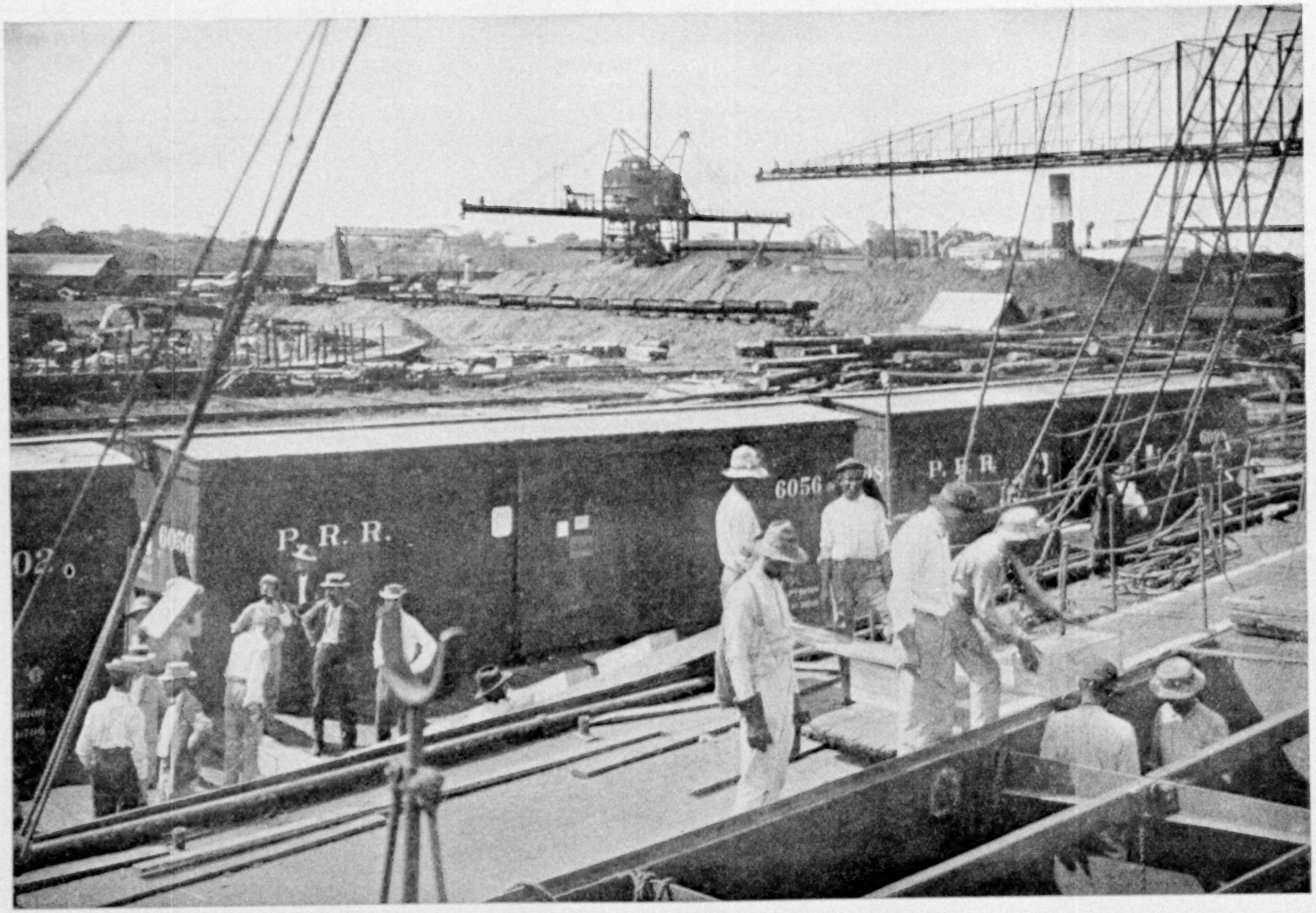
A NEARLY COMPLETED SECTION OF THE STORM SEWER IN "D" STREET, COLON, JULY, 1910
The lower half of the sewer is round and the upper half square



COLON HOSPITAL GROUNDS, NURSES' HALL, AND QUARTERS FOR PHYSICIANS

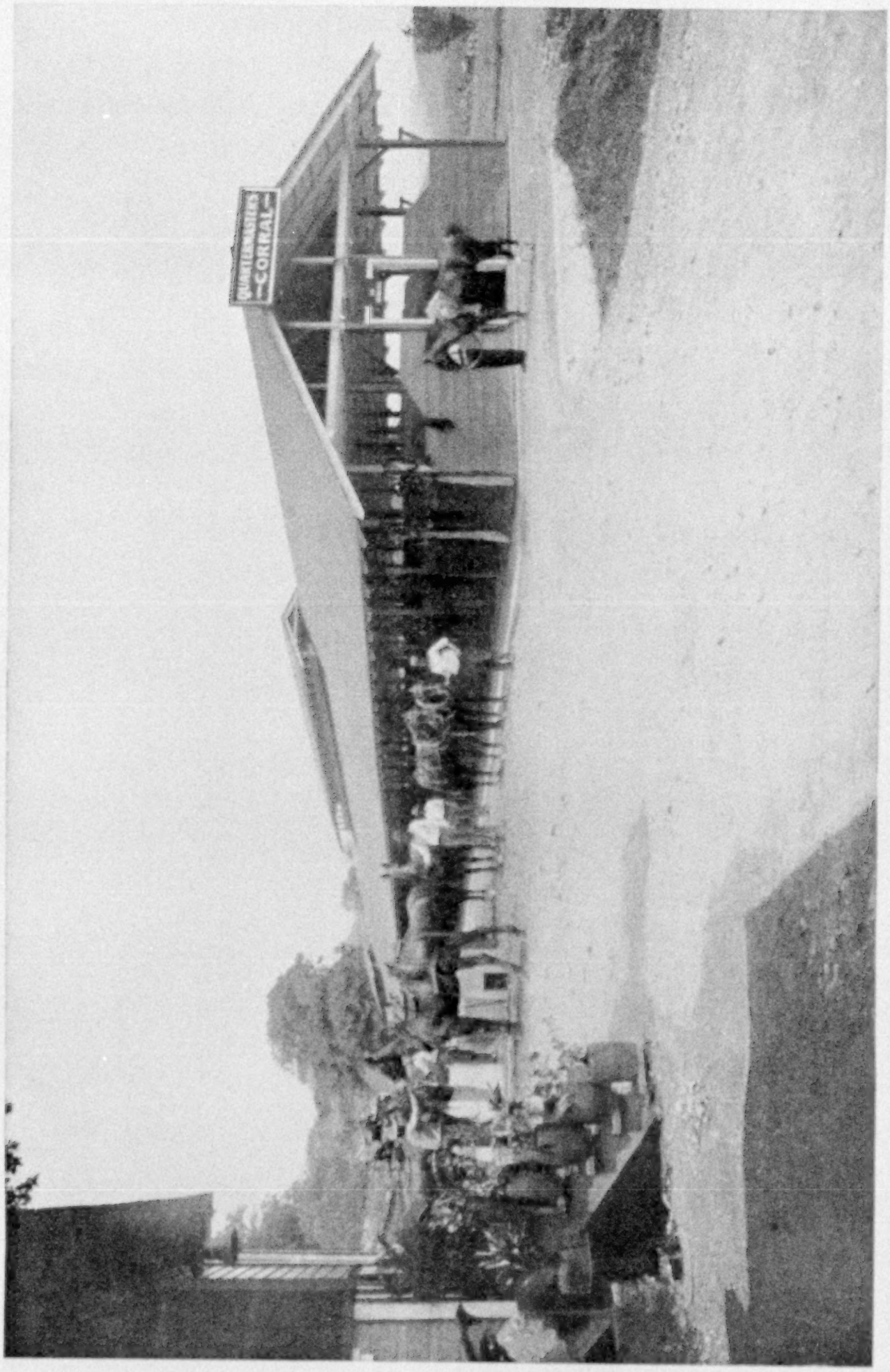
As the result of the care of the sanitary department, the health of the workmen is steadily improving. The daily average of sick in 1910 was 23.01 out of every thousand employed, compared to 23.49 for 1909, and 23.85 for 1908. The number of deaths among employees was 548, equivalent to an average of 10.84 per thousand, which would compare very favorably with the death rate of a similar class of people anywhere in the Temperate Zone. No cases of plague or yellow fever originated on the Isthmus. The deaths from typhoid fever among employees were only sixteen, one of whom was white and fifteen black, a remarkable record.

fever among employees were only sixteen, one of whom was white and fifteen black, a remarkable record.



UNLOADING DYNAMITE FROM SHIP AT PIER 13, MOUNT HOPE, CANAL ZONE: 1910

Last year 14,742,400 pounds of dynamite and blasting powder were shipped to the Isthmus for work on the canal (see page 173); 350,000 tons of material, valued at $10,103,552.34, were received from the United States during 1910. The value of local purchases, including coal and oil, was $2,094,131.02—345,185 tons of coal and 465,921 barrels of fuel oil were used.



QUARTERMASTER'S CORRAL AT ANCON, BUILT IN 1910

This is the largest corral on the Isthmus; 600 horses, ponies, and mules are owned by the department

Though at first confined to a length of 800 feet, measured along the line of excavation, the slide has extended to include the entire basin south of Gold Hill or for a length of about 3,000 feet. The original slide covered an area of about six acres, but the latest surveys show that is has extended to cover 47 acres.

NO DANGER FROM SLIDES AFTER CANAL IS COMPLETED

There are all told nine "slides" and "breaks" to be reckoned with, and there is nothing to do but to remove all the material embraced within their limits. As the cut is deepened these may be aggravated or others may develop. There is no method known to stop or to prevent them. Usually the first indication received, if there be a forewarning, is the lifting or moving of a shovel and tracks.

The cut has therefore developed into the uncertain and experimental feature of the work and its completion will mark the date of finishing the canal. No apprehension is felt because of the slides after the completion of the work. They develop as the depth of the cut increases, and the banks slide or break because of the condition of unstable equilibrium that results from the cutting; when grade is reached equilibrium will be established, and the back pressure of the water will result in greater stability. Whatever slides occur subsequently will be relatively small, and the material can be easily handled by steam shovels on the berms that will be left and by dredges that will be available.

Some idea of the magnitude of the slides can be obtained from the fact that during the fiscal year 1909, of 14,325,876 cubic yards removed, 884,530 cubic yards, or 6 per cent, were from slides. For the fiscal year 1910, of 14,921,750 cubic yards that were removed, 2,649,000, or 18 per cent, were from slides or breaks that had previously existed or that had developed during the year.

THE MATERIAL IS ALL ROCK

Except for the slides, which are of earth, the material to be removed is rock, and requires blasting to enable the shovels to handle it expeditiously. The largest part of the drilling is done by churn or well drills, though tripod drills replace them where the others cannot be used to advantage. The drills are operated by compressed air, supplied by three compressor plants, which are connected together by a 10-inch pipe line about five miles long, with 6-inch and 4-inch leads running into the cut. The drills operate in batteries of from 4 to 12; the holes, from 15 to 27 feet in depth, are spaced from 6 to 16 feet apart.

The explosive used is dynamite, 45 per cent to 60 per cent nitro-glycerine. Excessive moisture and water in the holes prevent the use of blasting powder. When the holes in any section are ready for blasting, they are "sprung"—that is, four to six sticks of dynamite are lowered to the bottom and exploded—thereby forming a chamber for the reception of the charge. The charges vary from 25 to 200 pounds, depending upon the local conditions; the tamping follows, and the explosion is effected by an electric current from one of the lighting plants.

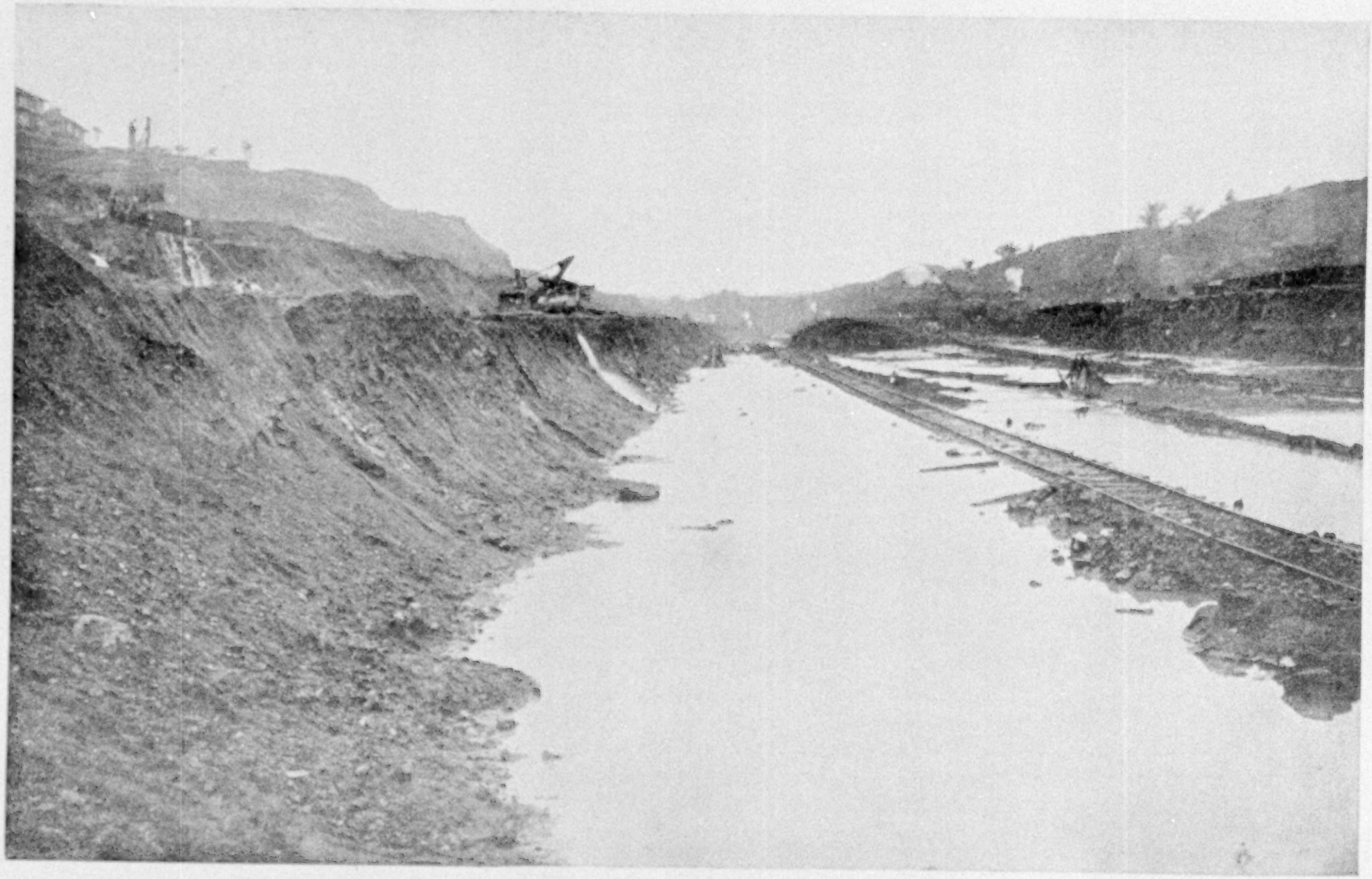
THE EARTH AND ROCK FROM THE CULEBRA CUT ARE USED FOR THE BREAKWATERS AND EMBANKMENTS

Through the blasted area the steam shovel cuts its way, averaging 34 feet wide at the bottom and 50 feet at the top for the "pilot cuts," which are 8 to 12 feet deep. The widening cuts are about 26 feet wide and from 15 to 24 feet deep.

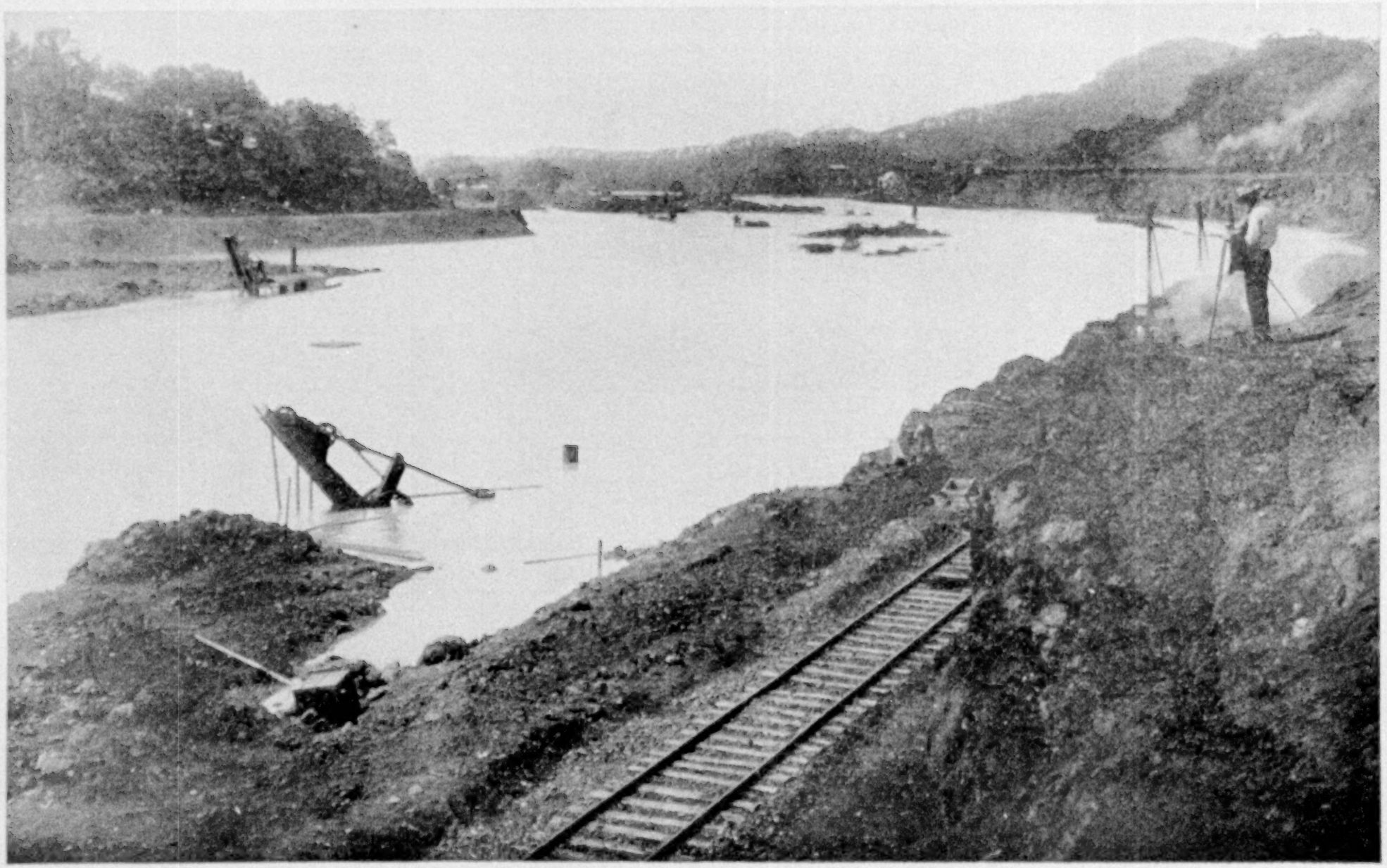
The best results are secured with the 95-ton shovels, though the 45-ton and 70-ton shovels are also used. The 95-ton shovels have dippers of four and five yard capacities, the former removing rocks containing as much as six cubic yards.

When the rocks are too large to be lifted by the shovel, they are "dobie" blasted, and thus broken to sizes convenient for the dipper. This is done by placing three or more sticks of dynamite on the rock, covering them with mud and igniting by means of a slow match.

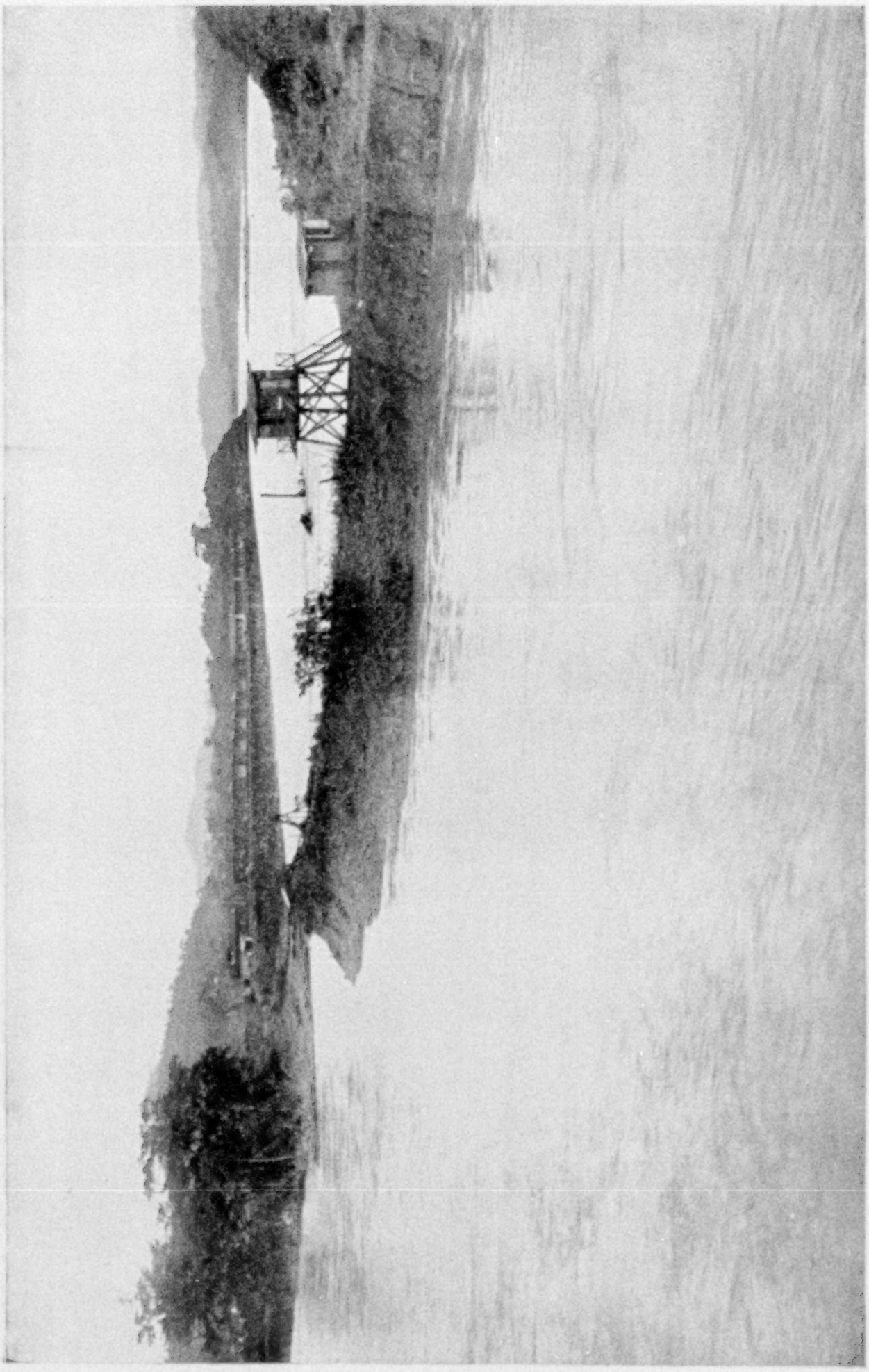
The shovels load the material on dirt trains, consisting of 20 flat cars and



CULEBRA CUT, OPPOSITE TOWN OF CULEBRA, LOOKING NORTH, JUNE 10, 1910, AFTER A HEAVY RAIN OF ONE HOUR
There is a record of 5.86 inches of rainfall in one hour



STEAM SHOVELS SUBMERGED IN THE CUT AT BAS OBISPO DURING A FLOOD (SEE PAGE 180)



THE CHAGRES RIVER BREAKING THROUGH A PROTECTION DIKE AND FLOODING THE CANAL (SEE PAGE 167)

The Chagres River has been known to rise 25.6 feet in 24 hours

from 25 to 35 steel side dumps to a train. The available dump grounds in the vicinity of the cut were utilized to their fullest capacity by the French and during the earlier periods of American control, so that longer hauls are necessary.

The new line of the Panama Railroad, being above the lake level, requires many heavy embankments, which offer suitable places for depositing material. The breakwater from Balboa to Naos Island offers a dump, though requiring an average haul of 11 miles.

As difficulty is experienced in extending this breakwater, additional dump tracks are provided at Balboa, so as not to delay the trains, and land at the inner end of the breakwater is being reclaimed; already 253 acres have been filled in. The interior swamps in the vicinity of Ancon are also to be filled. From 16 to 22 trains of material are sent daily to Gatun, an average haul of 25 miles, and used in building up the toes of the dam or for large rock to place in the concrete. The remainder of the excavated material is wasted on extensive dumps at Miraflores. A large dump ground at Tabernilla was used, but is abandoned for the present.

The Lidgerwood flats are dumped at Miraflores, Balboa, and on the relocated line of the Panama Railroad, where special equipment is kept to handle them, consisting of plows, unloaders, spreaders, and track-shifters. The plow is attached to one end of the train, and the unloader, consisting of a steam-driven drum on which is wound the cable, at the other end. To stretch the cable, the train passes between two uprights to which the cable is attached temporarily, and by moving the train the cable is drawn from the drum to the plow to which the end of the cable is attached. Winding the cable on the drum draws the plow the length of the train, removing the load.

After the material is plowed off, the spreader performs its functions, and, when no longer capable of throwing the material beyond the edge of the dump, the track is shifted by a device patented by W. G. Bierd, formerly general manager of the Panama Railroad, which raises by one motion the track with the ties so as to clear the ground, and by another motion pulls it sidewise. The usual throw is two and a half to three feet, though, if the rails will permit, the track can be thrown as much as nine feet in one throw (see page 179).

The steel dump-cars require no special or extra appliance for their operation, and can be dumped as easily on curved as on straight track. They also dump to either side.

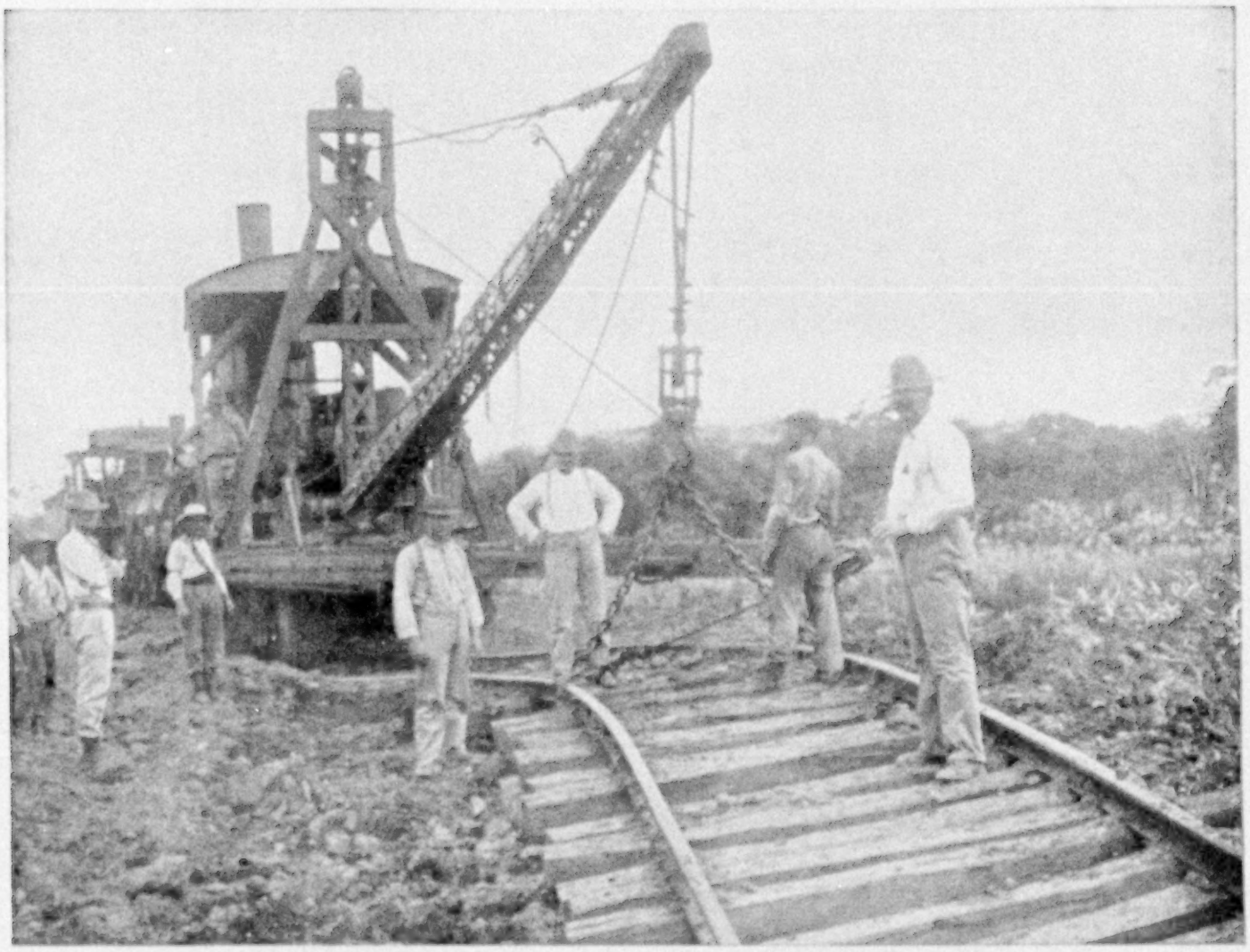
Work has been in progress on the Culebra Cut since 1880, and during the French control 18,646,000 cubic yards were removed. Between Gatun and Bas Obispo, the northern end of Culebra Cut, the French excavation which is useful to the present project amounted to 2,201,000 cubic yards, or a total in the Central Division of over 20,000,000 cubic yards. The total estimated amount of material to be excavated from May 4, 1904, in this division was 97,125,018 cubic yards, of which, up to January 1, 1911, 67,792,855 cubic yards have been removed, or 69.7 per cent. It is expected that all the excavation in the lake section will be finished by July 1, 1911.

Some idea of the magnitude of the operations may be formed from the fact that this division has within its jurisdiction over 200 miles of 5-foot-gauge track laid, about 55 miles of which are within the side slopes of the Culebra Cut alone.

THE GREAT DAM AT GATUN IS A VERITABLE HILL

An earth dam across the Chagres at Gatun impounds the water of the river and creates the lake which constitutes the summit level. The dam is 7,500 feet long over all, measured along the top, and, according to the latest profile, it is 2,100 feet wide at the base, 398 feet through at the water surface, reference 85, and 100 feet wide at the top, which is 115 feet above sea-level. It crosses two valleys separated by a hill rising to elevation 110, in which the regulating works are being constructed. Of the total length of the dam, only 500 feet

DEPOSITS OF SAND AND GRAVEL BROUGHT DOWN BY HIGH FLOODS OF THE CHAGRES RIVER IN NOVEMBER AND DECEMBER, 1909



TRACK-RAISING AND SHIFTING MACHINE

This powerful machine lifts the track and ties clear of the ground and then deposits them from three to nine feet away. It bends the steel rails as easily as if they were made of clay (see page 177).

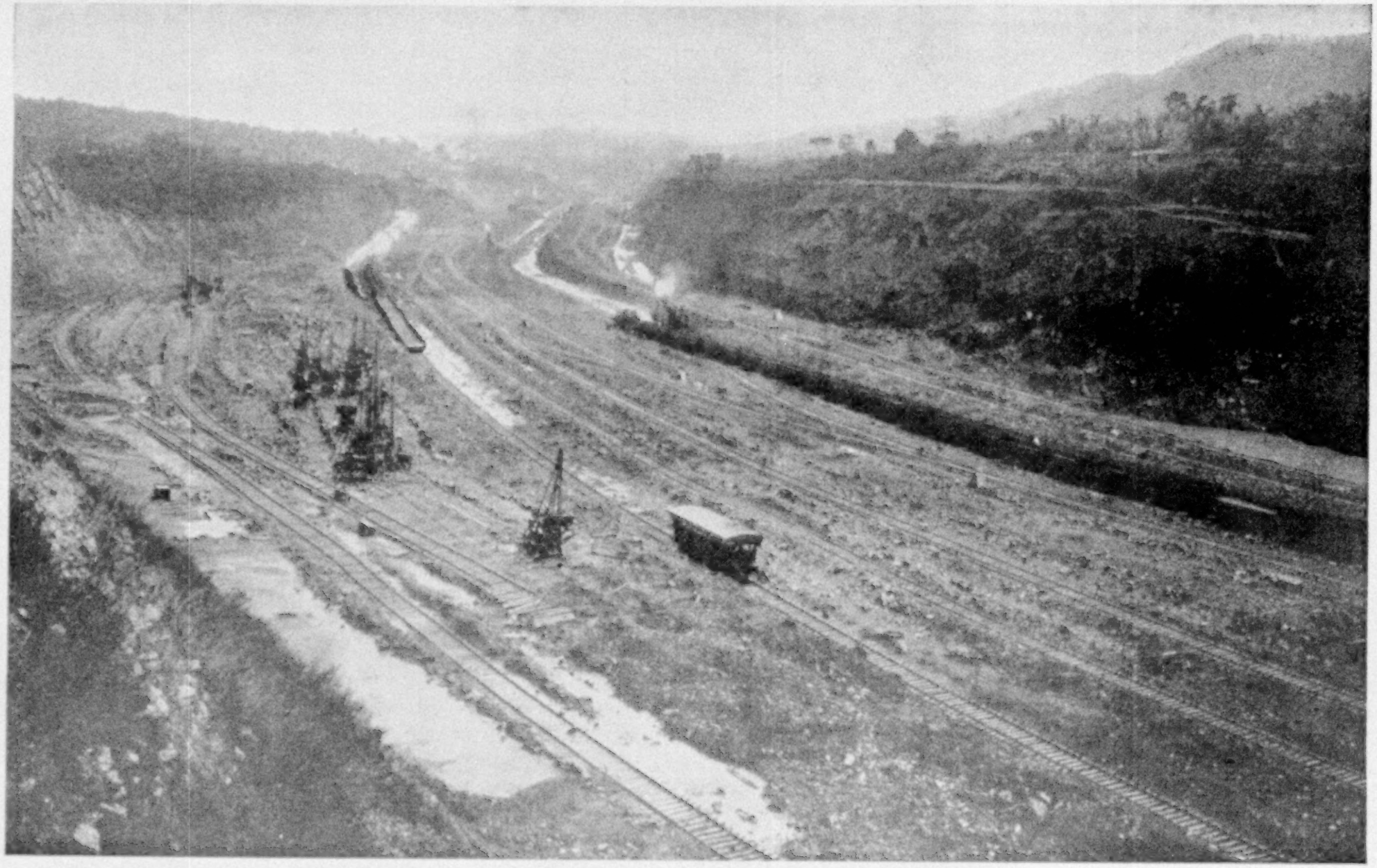
will be exposed to the maximum head of 85 feet, the remainder to less.

The dimensions of the dam have been criticised as excessive and unwarranted, but its designers considered it desirable, in view of the amount of material available, that ample provisions be made against every force which may affect its safety, and that a barrier be made so that the layman without engineering knowledge would recognize its stability. Now that the dam is assuming appreciable proportions, this latter object is more than realized.

The dam in plan is a broken line to conform to the configurations of the natural surface, thereby materially reducing the fill. It extends from the hill in which the locks are to be constructed to Spillway Hill, thence along the spur or hog-back of the hill on the west side of the valley (see map, page 201).

The adoption of the earth dam brought on such criticism that an exhaustive examination of the foundations was made in order to determine more carefully the character and extent of the various underlying materials; to ascertain whether there was any possible connection between the swamp areas to the north and south through the deposits in the gorges across which the dam will be built; for testing the ability of the material to support the proposed structures, and for learning whether suitable material for the dam could be obtained in the immediate vicinity.

As the result of the investigations, it



CUT AT EMPIRE, LOOKING NORTH

In the upper right-hand corner is seen the break in the rock bank which let the Obispo diversion into the canal for three days, drowning out some of the shovels at the north end. This break aggregates about 40,000 cubic yards, but will not be disturbed until the dry season. A flume has been constructed of timber and concrete to carry the flow of the diversion past the break (see page 175).

may be briefly stated that the underlying material is impervious to water; that it possesses ample strength to uphold the structure that will be placed upon it, and, the subsoil being impervious, that there is no connection between the swamps above and the sea below.

Because of the sluggish current of the river in the vicinity of Gatun and above, the deposits consist of the finer sands and silts interspersed with beds of clay. By constructing experimental dams of this material and subjecting them to the full head of water, it was conclusively demonstrated that this material is suitable for the interior or the impervious core.

The dam is constructed by forming two dumps on the outer lines of the structure and depositing waste material, mostly rock, obtained from Culebra, the lock site, and Mindi. The area between the piles thus formed is filled with the material pumped in by hydraulic dredges, the natural surface of the ground having been previously cleared of vegetation and a suitable bonding trench excavated.

THE SPILLWAY

Fluctuations in the lake due to floods are to be controlled by regulating works constructed in Spillway Hill. Objections were made to constructing such works in the line of the dam, but because of the natural configuration of the ground, irrespective of the location of the spillway, provision had to be made for tying the dam to the sides of the hill; moreover, the extent and elevation of the hill, as well as the material composing it, make it a suitable and desirable place for the waste weirs. The channel has been cut, the floor and side walls of concrete completed, and the Chagres River now discharges through it. As the reference of the floor is at 10 feet above sea-level, the lake is already formed at least to this height.

The spillway dam will be of concrete with its crest at elevation 69. Piers 8.5 feet wide will be built on top of the crest, 53.5 feet centers, grooved for Stoney gates, which will close the openings and complete this portion of the dam. The trace of the dam will be the arc of a circle 740 feet long, with 14 openings, which, when the gates are raised to the full height, will permit a discharge of 140,000 cubic feet per second. The water discharged over the dam will pass through a diversion channel into the old bed of the Chagres. (See map, page 201.)

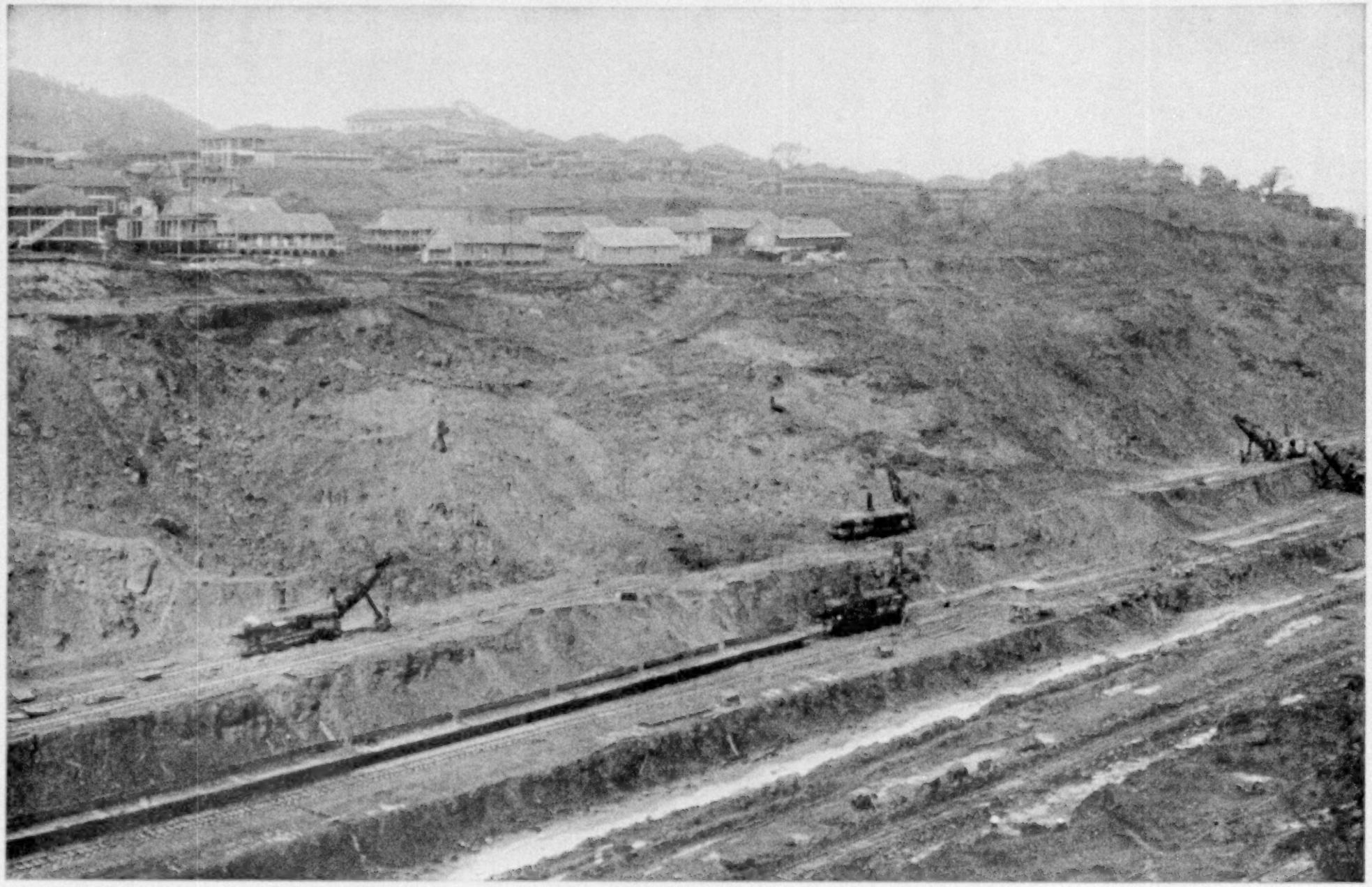
The dam is to contain 21,145,931 cubic yards of material. On January 1, 1911, there had been placed 12,001,592 cubic yards, making 56.72 per cent of the dam complete. The spillway will contain an estimated quantity of 225,485 cubic yards of concrete, of which 113,269 cubic yards, or 50.23 per cent, were completed on January 1.

THE LOCKS CAN BE FILLED OR EMPTIED IN 8 MINUTES

The locks are in pairs, so that if any lock is out of service navigation will not be interrupted. Thus, also, when all the locks are in use, the passage of shipping will be expedited by using one set of locks for the ascent and the other for descent. The locks are 110 feet wide and have usable lengths of 1,000 feet.

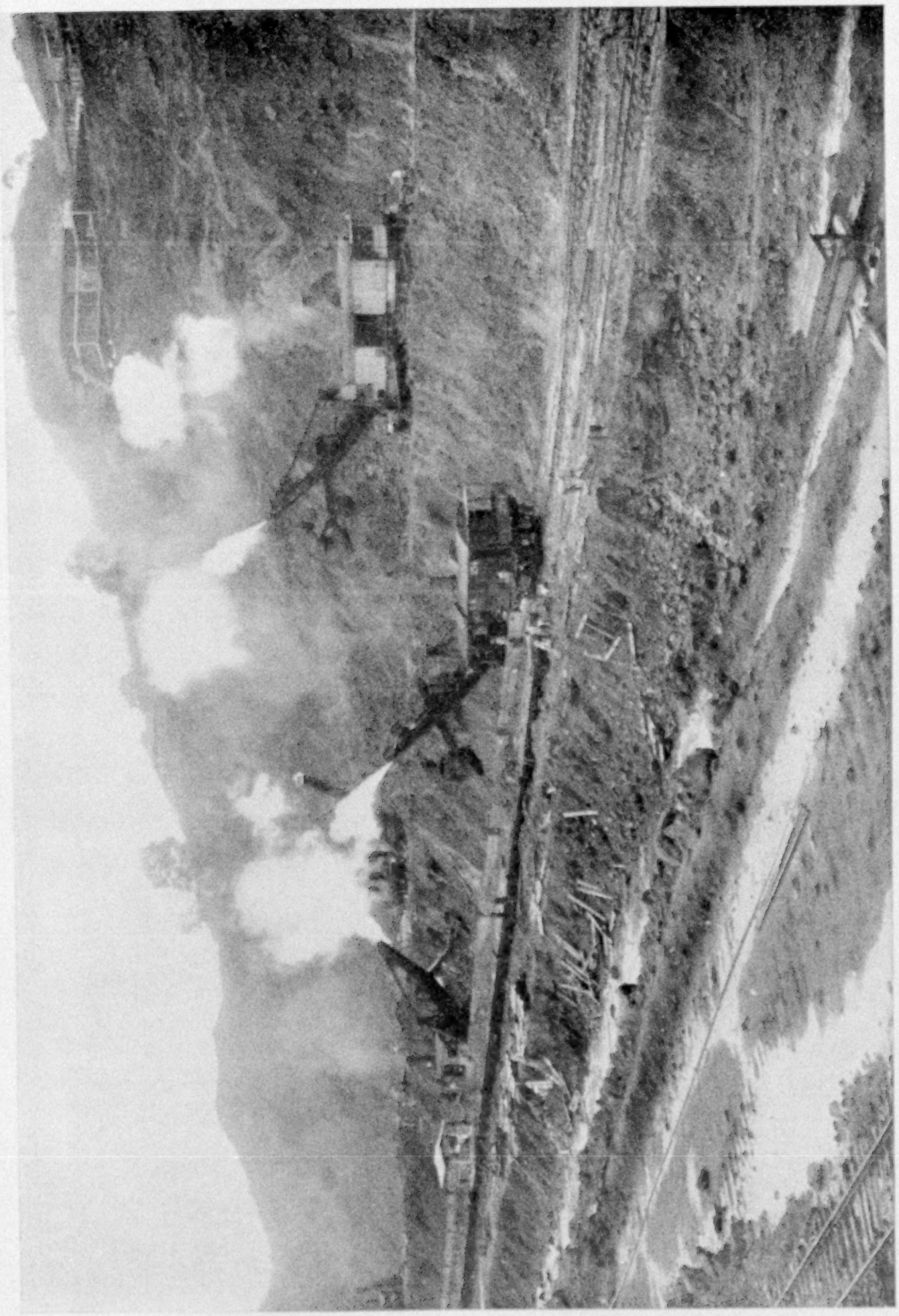
The system of filling adopted consists of a culvert in each side wall feeding laterals perpendicular to the axis of the lock, from which are openings upward into the lock chamber. This system distributes the water as evenly as possible over the entire horizontal area of the lock, and reduces the disturbance in the chamber when the latter is being filled or emptied. (See diagram, page 202, and illustrations, pages 206-207.)

The middle or separating wall contains a single culvert of the same area as the culverts in the side walls, which feeds in both directions through laterals controlled by valves designed to operate against a head from either direction. This arrangement permits communication between the chambers of twin locks, so that water may be passed from one lock to the other of the pair, effecting a saving of water. The main culverts are controlled by Stoney valves, and the lat-



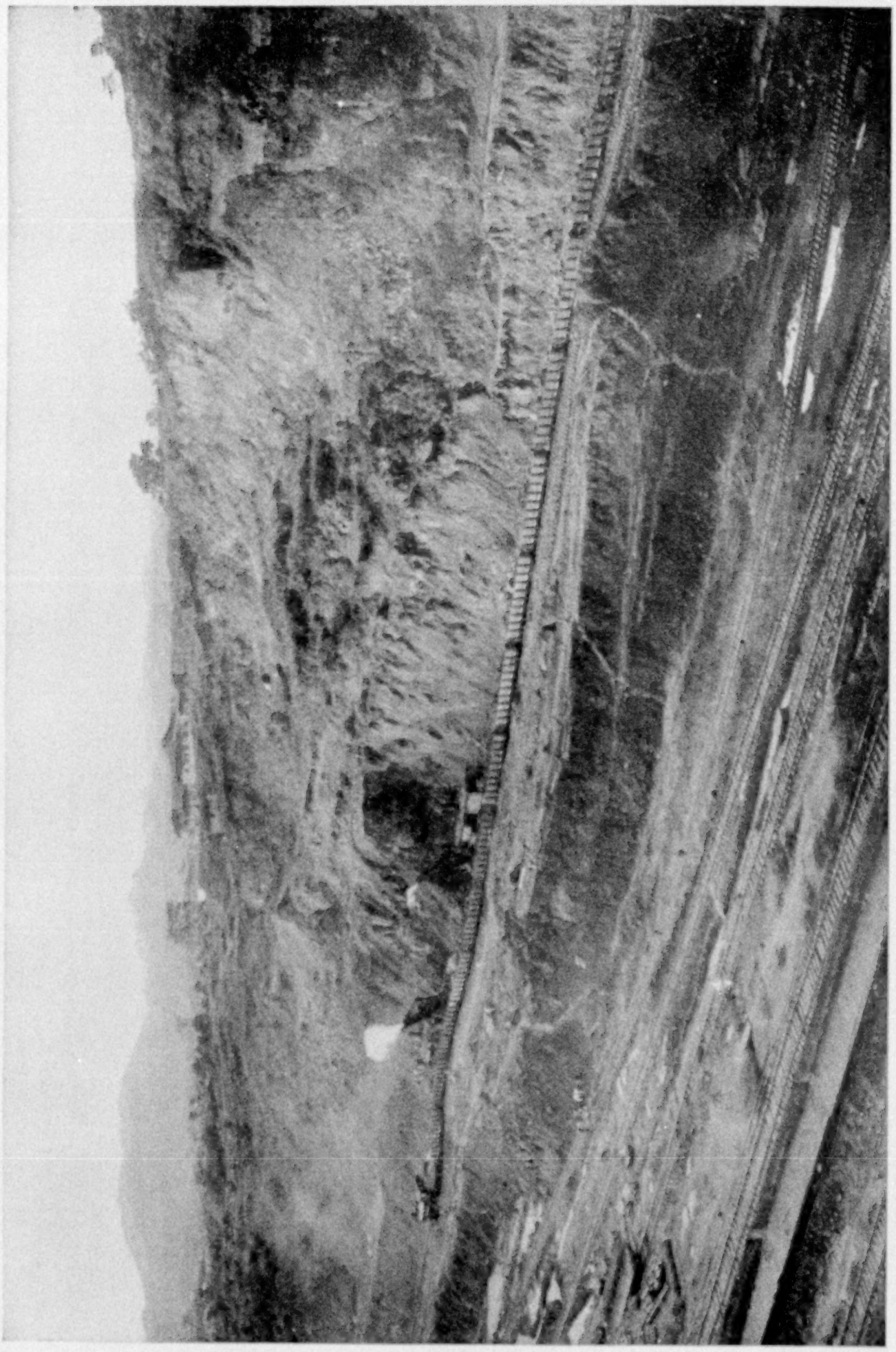
BREAK IN THE WEST BANK OF THE CANAL AT CULEBRA

Note the successive benches on which the shovels work (see page 167). Nearly one-fifth of all the material removed from Culebra Cut in 1910 was from slides and breaks like this

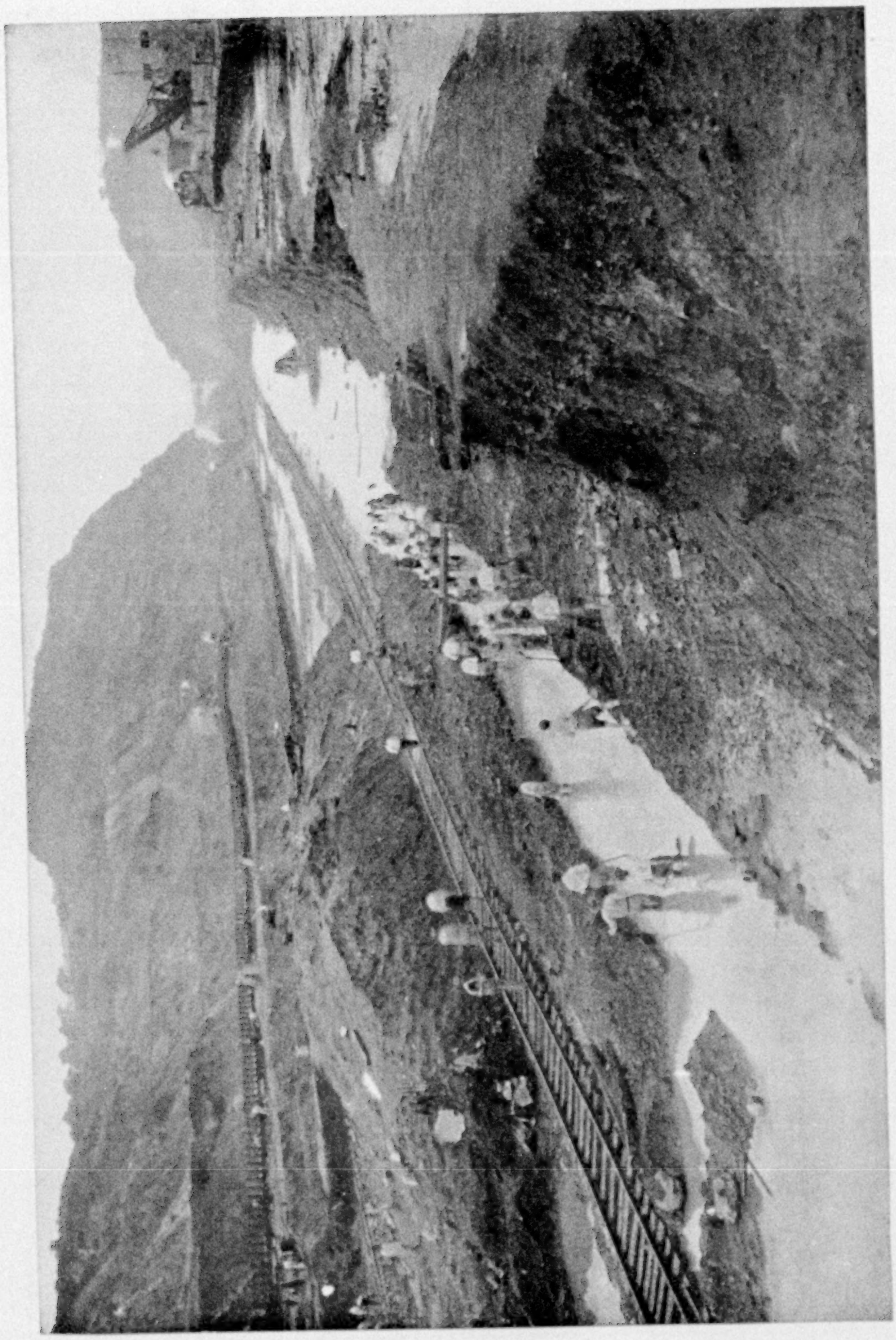


ANOTHER VIEW OF THE BREAK IN THE WEST BANK AT CULEBRA, SHOWING FOUR STEAM SHOVELS WORKING ON THE BROKEN AND MOVING MASS

The two upper shovels are casting material over the berm, to be loaded by the two lower shovels into the Lidgerwood train. This break has necessitated the removal of nearly 2,000,000 cubic yards



BREAK IN THE EAST BANK OF THE CANAL, OPPOSITE CULEBRA, JUNE, 1910



BREAK IN THE EAST BANK AT CULEBRA

Showing how the pressure of the broken bank, shown in the preceding picture, has raised the bottom, for a short distance, to a height of 18 feet above its original level (see pages 167 and 173). A similar break advanced 14 feet in 24 hours, overturning the steam shovels and disheartening the men. There is no way to prevent these breaks.

CULEBRA CUT, LOOKING NORTH

erals leading from the center wall by cylindrical valves.

Assuming a difference of head of 30 feet, it is estimated that the entire lock can be filled or emptied, using one culvert in 15 minutes and 42 seconds, and in 7 minutes and 51 seconds when both culverts are used.

The lock gates are of the mitering type, double leaf, straight gates, varying in height from 45 feet 7 inches to 79 feet; the length of each leaf is about 65 feet. A contract has been entered into for furnishing the steel for the gates and for their erection in place by June 1, 1913. To meet this condition, it is necessary that the concrete work shall be completed in time to enable the contractors to begin the erection of the various sets of gates on the dates specified in their contract, and the work is being prosecuted with this end in view. To accomplish the result, the concrete for the Gatun locks must be finished by June 1, 1912, and that for the locks on the Pacific side by October of the same year.

SAFETY DEVICES

It has been accepted as a fundamental feature of the design that at each flight of locks there must always be two barriers separating the high level from the level next below. To carry this out, two sets of mitering gates are placed at the

upper and two at the lower end of each of the uppermost locks in each flight.

In addition a chain device is used to guard the barrier gates against accident, and so controlled as to be capable of checking a ship of 10,000 tons moving at the rate of about five miles an hour.

More than 95 per cent of the vessels navigating the high seas are less than 600 feet in length, and this has been taken as the determining factor for the location of intermediate gates, which are introduced in the design to save both time and water. For the protection of the intermediate gates against vessels using a smaller length of chamber a chain barrier is to be installed.

Guide piers are provided both upstream and down, to which vessels will tie before entering the locks. Designs for electric towing machines are being prepared, which will be used for towing vessels into and controlling their passage through the locks by means of lines or cables attached to what may be considered the four corners of the ship.

Even with all of these precautions accidents may happen, and emergency dams are provided at the head of each flight of locks, consisting of swing bridges, which can be thrown across the locks in case of an accident which makes a connection between the top level and the level below; wicket girders are let down from these swing bridges, supported by a sill at the bottom and the horizontal truss work of the bridge at the top. These wicket girders act as runways for gates, which are lowered and gradually stop the flow.

GATUN LAKE WILL STORE WATER FOR THE DRY SEASON

It will not be out of place at this point to give consideration in a general way to the question of adequacy of the water supply to maintain a large commerce through the locks. Data bearing on the subject have been collected for many years and studied with care. During eight or nine months of the year there is more than a sufficient supply for all purposes, but during the other four or three months there is practically none, and it becomes necessary to store a sufficient quantity during the rainy season to supply the needs during the dry season.

The enormous reservoir of Gatun Lake is available for this purpose. The bottom of the canal in the summit level is at reference 40, and it is evident that navigation, with the extreme depths provided of 40 feet in sea water, can be carried on until the surface of the lake falls to reference 81⅔. As the water surface in the lake is to be allowed to rise to reference 87, there is stored available for the dry season a little more than five feet.

Making due allowances for power consumption, evaporation, about which data are available, seepage and leakage at the gates during a dry season of minimum flow, assumed as following a wet season of minimum flow, an average of 41 passages of the canal per day is possible, using the full length of lock. In the average dry season 58 complete transits of the canal are possible, or a greater number than the 24 hours of the day would permit, allowing vessels to follow each other at intervals of one hour.

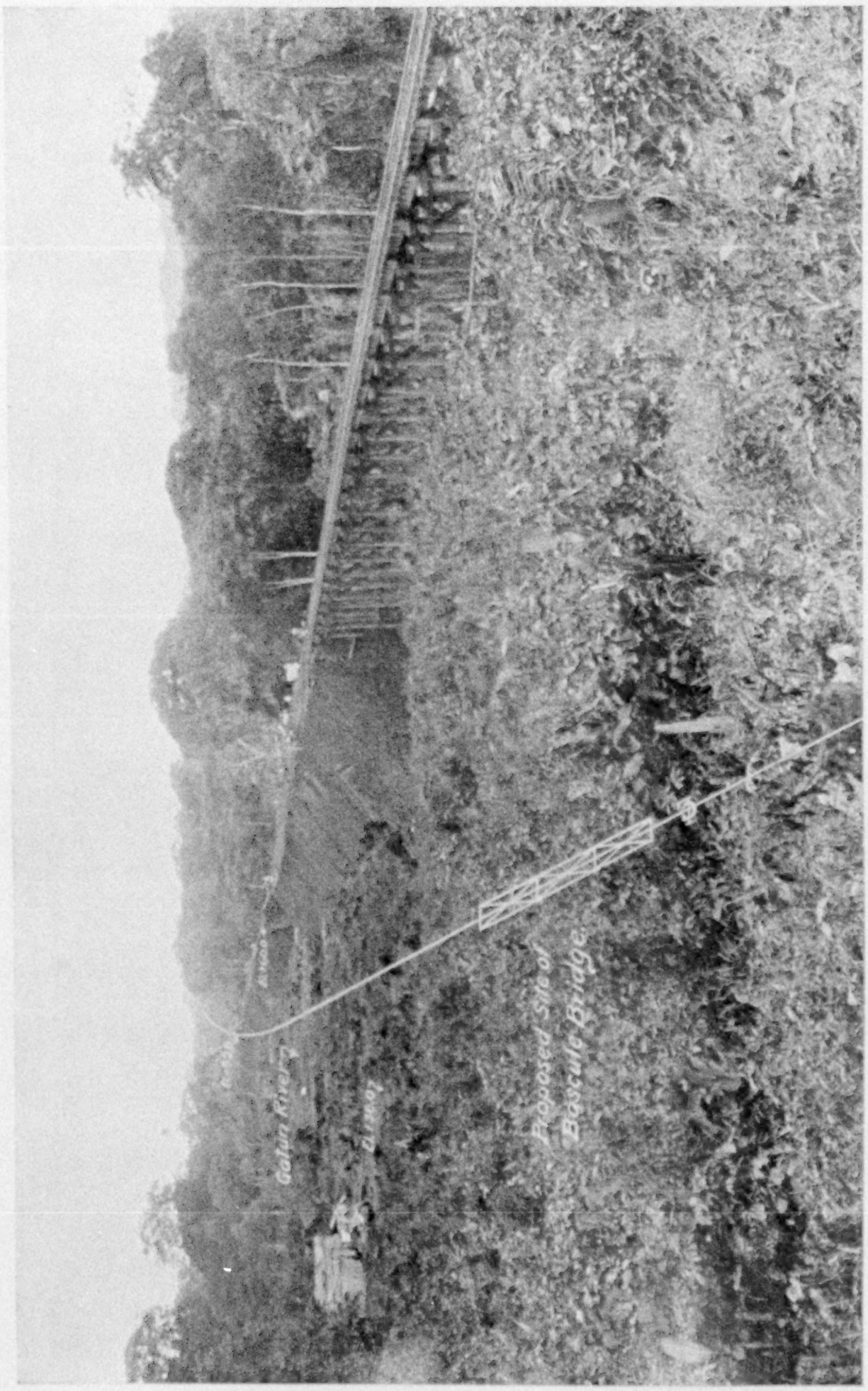
With the design for the locks as adopted a certain amount of water can be saved at each lockage whenever a vessel does not draw the full permissible depth of 40 feet by cross-filling or emptying through the middle wall. As a consequence it can be stated that there will be sufficient water for as many lockages as the time in the day will permit.

INGENIOUS METHODS FOR HANDLING THE ROCK AND CEMENT

At Gatun three locks in flight overcome the difference in level between the lake and sea, and are being constructed in a cutting made through a hill. The excavation, consisting of upwards of 5,000,000 cubic yards, mostly rock, is practically completed. The locks are of concrete, and contain about 2,046,100 cubic yards of this material. On January 1 last they were 49 per cent completed.

A TEMPORARY TRESTLE ACROSS THE BRAZO BOTTOM, LOOKING SOUTH

One of the most difficult tasks connected with the canal is to relocate and rebuild the Panama Railroad, and at the same time not to interfere with the tremendous traffic across the Isthmus. The large lake which is being created by the Gatun Dam will completely submerge the present railway for the greater part of its length. This illustration shows a depression, across which an embankment nearly a mile long, and containing 1,500,000 cubic yards of earth and rock, must be built to hold the railway above the level of the lake.



RELOCATING THE PANAMA RAILROAD ACROSS THE VALLEY OF THE GATUN RIVER: THIS EMBANKMENT WILL BE THREE-FOURTHS OF A MILE LONG AND CONTAIN 1,000,000 CUBIC YARDS

BUILDING GATUN DAM BY HYDRAULIC FILL: LIFT, 63 FEET; LENGTH OF PIPE, 4,300 FEET

The dam is constructed by forming two dumps on the outer lines of the structure and depositing waste material, mostly rock, obtained from Culebra, the lock site, and Mindi. The area between the piles thus formed is filled with the material pumped in by hydraulic dredges, the natural surface of the ground having been previously cleared of vegetation and a suitable bonding trench excavated.

The broken stone for the concrete is quarried and transported from Porto Bello, about 20 miles east of Colon, and the sand is procured from Nombre de Dios, about 20 miles farther to the east. Both are transported direct to Gatun in barges through the French Canal, which was dredged of rock ledges and accumulated deposits for the purpose. Since the canal line was cut through to the French Canal this new channel is also used. The cement is purchased under contract at docks in Jersey City and shipped to Cristobal, thence by barges to Gatun or cars to Pedro Miguel and Miraflores.

The material taken to Gatun in barges is landed at unloading docks, conveniently located on the old east diversion, to which a channel from the French Canal was excavated by dredges. The east dock is inclosed, forming the cement storehouse. Its floor dimensions are 106 feet by 490 feet. The roof projects 35 feet beyond the face of the dock, affording some protection against the rains.

The building is divided into ten bays, in each of which a two-ton traveling crane, worked by electric motors, operate entirely across the building. In the rear of the building 30 cement hoppers are placed in the floors and covered with steel screens. The cement is delivered through these hoppers into cars running on a track below the floor. The cement for this work is in barrels, which are first put into the storehouse and subsequently moved to the hoppers.

Grab buckets, operated by cableways, remove the sand and stone from the barges, moored against the west dock, and deliver the materials in stock piles. The towers of the cableways are of steel, 85 feet high and 800 feet apart. They are mounted on cars, which enable movement at right angles to the line of the cable; one single and two duplex cableways are provided. (See illustration, page 196.) Each of the latter have complete independent cableway systems. The cableways are equipped with five 70 cubic feet self-digging grab buckets, each having an independent run from the barge to the stock pile. The cableways have not the capacity to unload the material required with sufficient rapidity, and have been augmented by three derricks operating on a dock north of the cement shed, transferring sand and stone to bins.

THE AERIAL CABLEWAYS

Two tunnels run north and south through the stock piles, with hoppers in the top through which stone and sand are fed to cars.

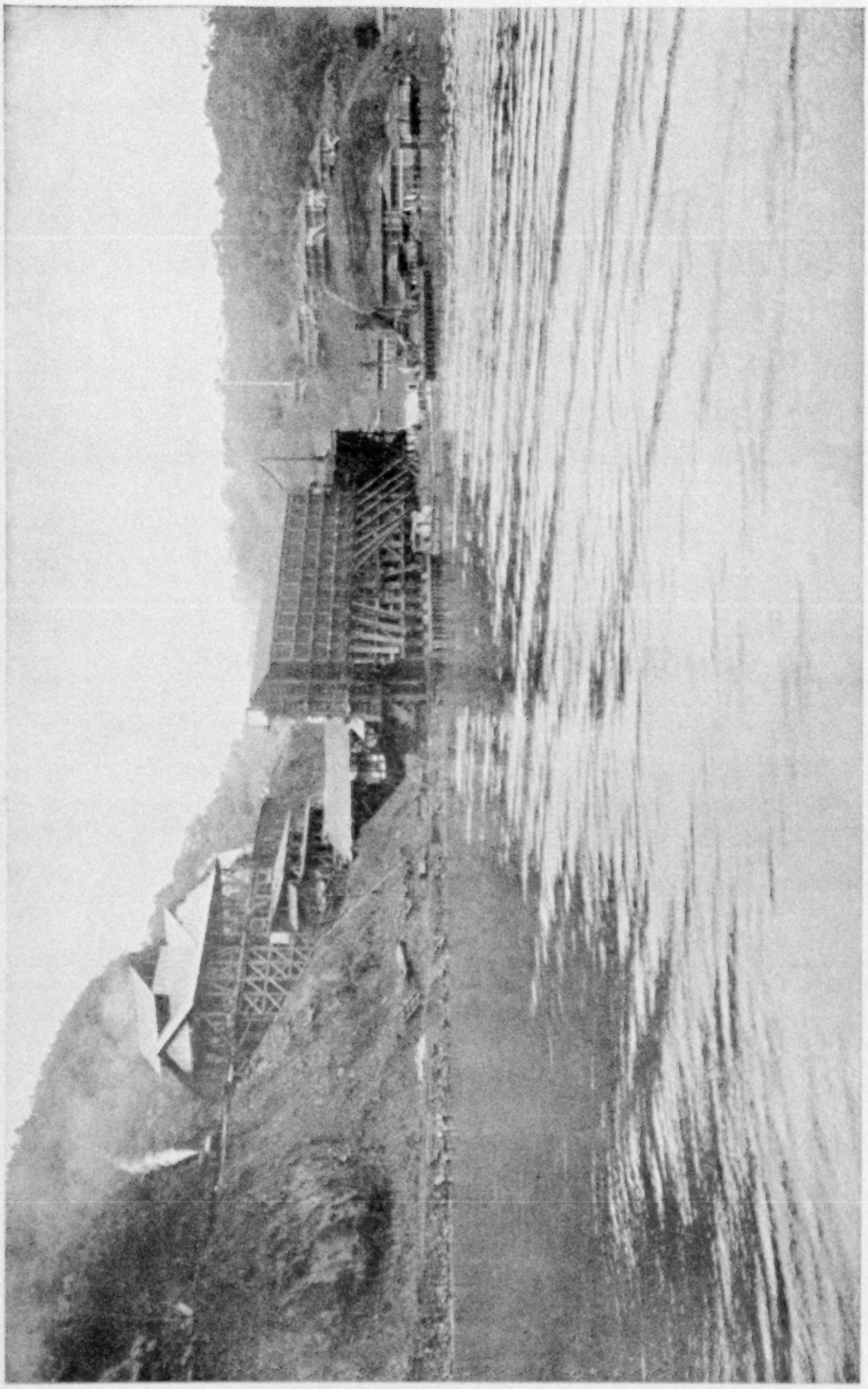
The cars used for transferring the material are of steel with hinged side doors, and bottoms inclined outward at an angle of 52 degrees from the horizontal. A steel partition divides each car into compartments, one for rock and cement and one for sand. The car starts at the cement shed, where it receives two barrels of cement, thence runs through one of the tunnels, receiving a full charge of stone and sand in the proper compartment, and proceeds to deliver this load in the mixer hopper.

The concrete mixers are of the cubical type, each having a capacity of 64 cubic feet. There are eight of them, all mounted in one building on the west side of the lock site, arranged so that four dump in one direction and the other four directly opposite, thus permitting the use of two tracks under the mixers. There is, however, but one track above.

A four-track electric railway, third-rail system, operates the length of the locks and carries the concrete from the mixers to the cableways over the locks, by which it is placed. The equipment for this road consists of 12 electric four-wheel mine-locomotive-type engines and 24 flat cars fitted with automatic couplers, each designed to carry a two-yard concrete bucket. Two charges of concrete are taken by each train and carried to the cableways.

Four duplex cableways span the locks with steel towers 85 feet high and 800 feet apart, similar in design to the unloading cableways.

The forms used in concrete laying are



VIEW OF PORTO BELLO QUARRY, ABOUT 20 MILES EAST OF COLON, SHOWING CRUSHING PLANT AND SHIPPING BINS

This plant, owned by the government, supplies the crushed stone for the concrete work at Gatun. The amount of stone quarried and crushed in the fiscal year 1910 was 540,678 cubic yards, at an average cost for the last six months of $2.6283 per cubic yard delivered in the stock-pile at Gatun, this cost including plant charges and division expenses. The greatest month's output was in June—a total of 74,184

of steel and, for the straight portion of the walls, so designed as to permit construction of monoliths 36 feet in length extending from the floor to the top of the walls. The forms for the main and the lateral culverts are of steel and are collapsible.

FROM GATUN TO THE OCEAN

The channel from the locks to deep water in Limon Bay, approximately seven miles in length, is being excavated in part by steam shovels and the remainder by dredges.

South of the French Canal the Mindi Hills cross the line of our canal between Gatun and Limon Bay, rising to the elevations 50 and 60. As the bulk of the excavation is rock, steam shovels were put to work to secure the requisite width and depth. It was thought that when sea-level was reached the shovels would have to be replaced by dredges, as the Mindi River is within a few hundred yards of the area, and the French Canal borders it. As the work progressed, however, notwithstanding the seamy nature of the rock, it was found that a relatively narrow levee would keep out water from the French Canal, and the seepage was so small as to be easily handled by pumps. One shovel-cut to grade was made, when the high water in December, 1909, flooded the pit and work was suspended until recently, when the soft material was removed by a suction dredge. The water is being pumped from the pit so as to permit completion of the work by steam shovels.

Over the area to be dredged, a seagoing suction dredge removes the softer material, while ladder and dipper dredges handle the rock and stiff clays. The underlying rock is drilled and blasted prior to dredging. A total of over 35,000,000 cubic yards was the estimated amount to be excavated, of which 60.3 per cent is completed.

THE LOCKS AT PEDRO MIGUEL

In the Pacific Division the work consists of the construction of duplicate locks at Pedro Miguel overcoming a 30-foot difference of level, with the necessary dams; two locks in flight, also in duplicate, at Miraflores, connected with the adjacent hills by one earth and one concrete dam; excavating the channels between the locks to the required depths, and the excavation of the channel to proper width and depth to deep water in the Pacific.

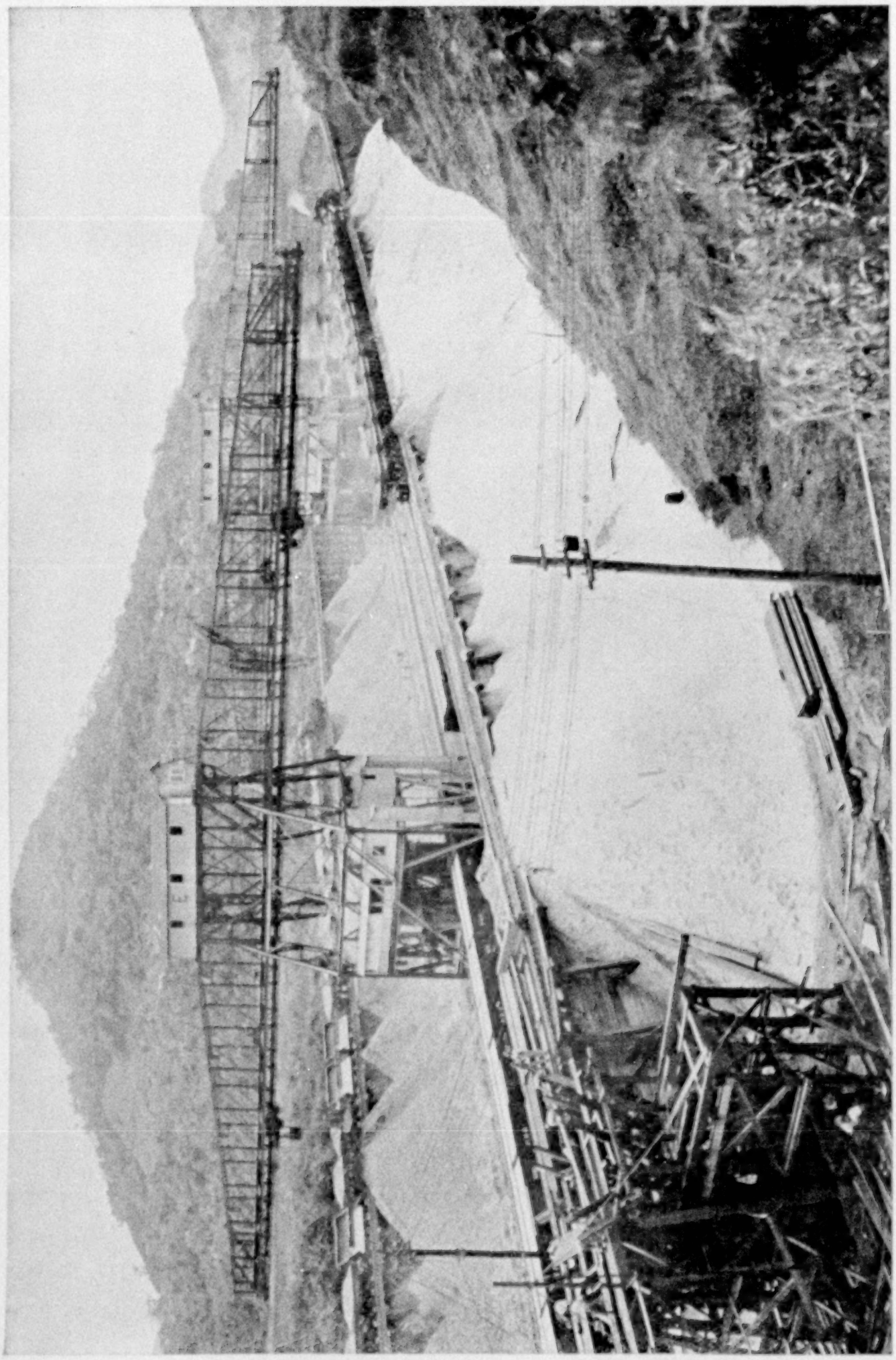
The Pedro Miguel locks connect the summit or 85-foot level with the 55-foot level. The excavation for the locks, amounting to 770,000 cubic yards, is completed, and of the 837,400 cubic yards of concrete required for their construction, 57 per cent is completed.

The west dam connects the head of the locks with the hills to the northwest and performs the same function at the south end of the lake that the Gatun dam does at the north. It is to be of earth, about 1,400 feet long, 40 feet wide at the top, which will be at reference 107 above mean tide, and have side slopes of 8:1. It will be subjected to a maximum head of 40 feet, though the average head is from 25 to 30 feet.

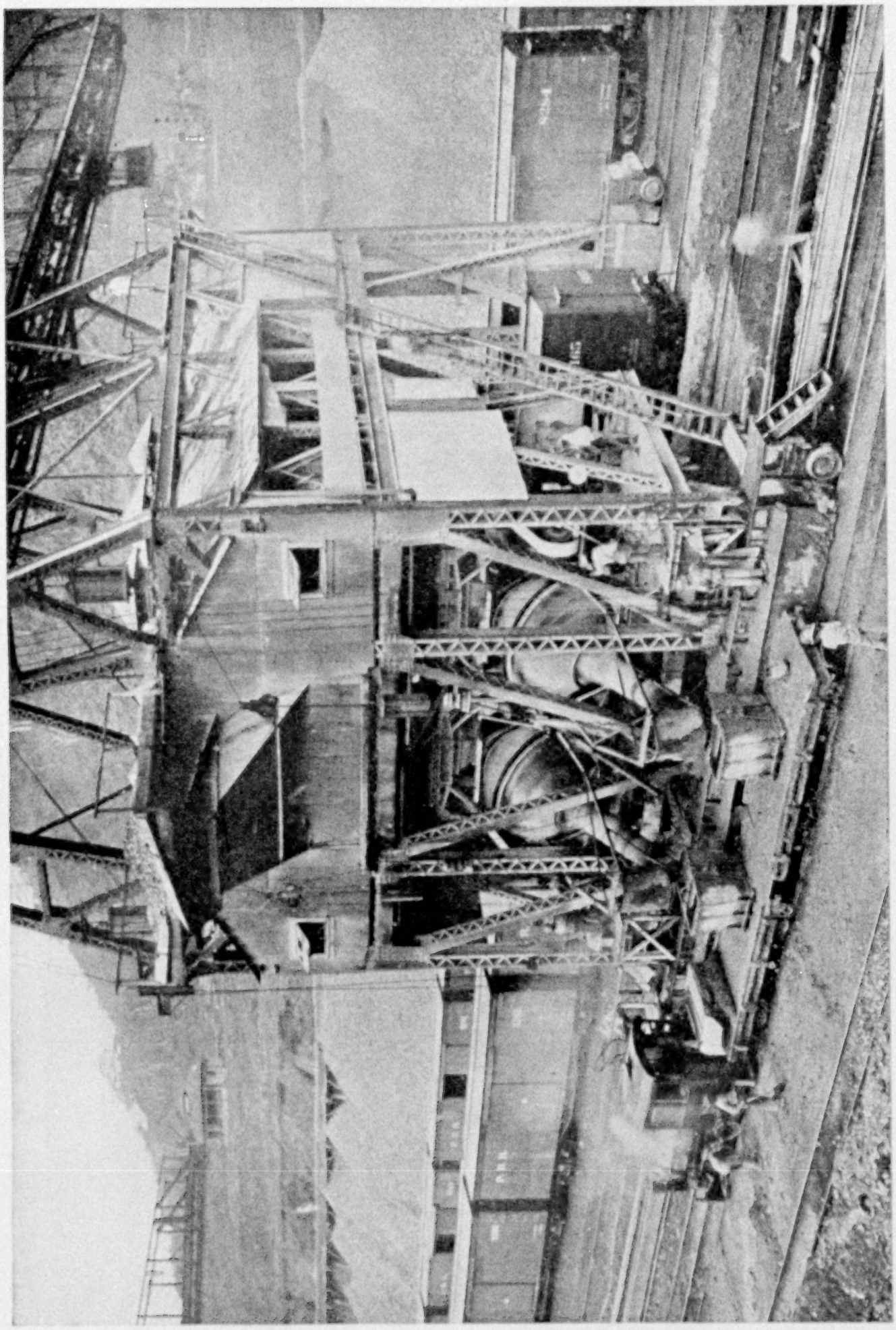
In its construction two rock piles are formed; between these two masses of material (from which an existing stratum of gravel was removed), selected material will be placed properly puddled and rolled. This central portion will have a thickness of 140 feet at the bottom. Concrete core walls will connect the dam with the hill and lock. The dam, which contains about 1,000,000 cubic yards, is 26 per cent completed. The natural surface of the ground from the east wall to an adjacent hill is above the upper level, but it is to some extent pervious to water. To cut off any possible flow, the lock wall is returned toward the hill, with which it will be connected by a concrete core wall.

THE LOCKS AT MIRAFLORES

The Miraflores locks are two in flight, overcoming the difference in level between Miraflores Lake, whose surface is at reference 55, and the sea-level section. As the fluctuations in tide are about 20 feet and mean tide is the datum, it will

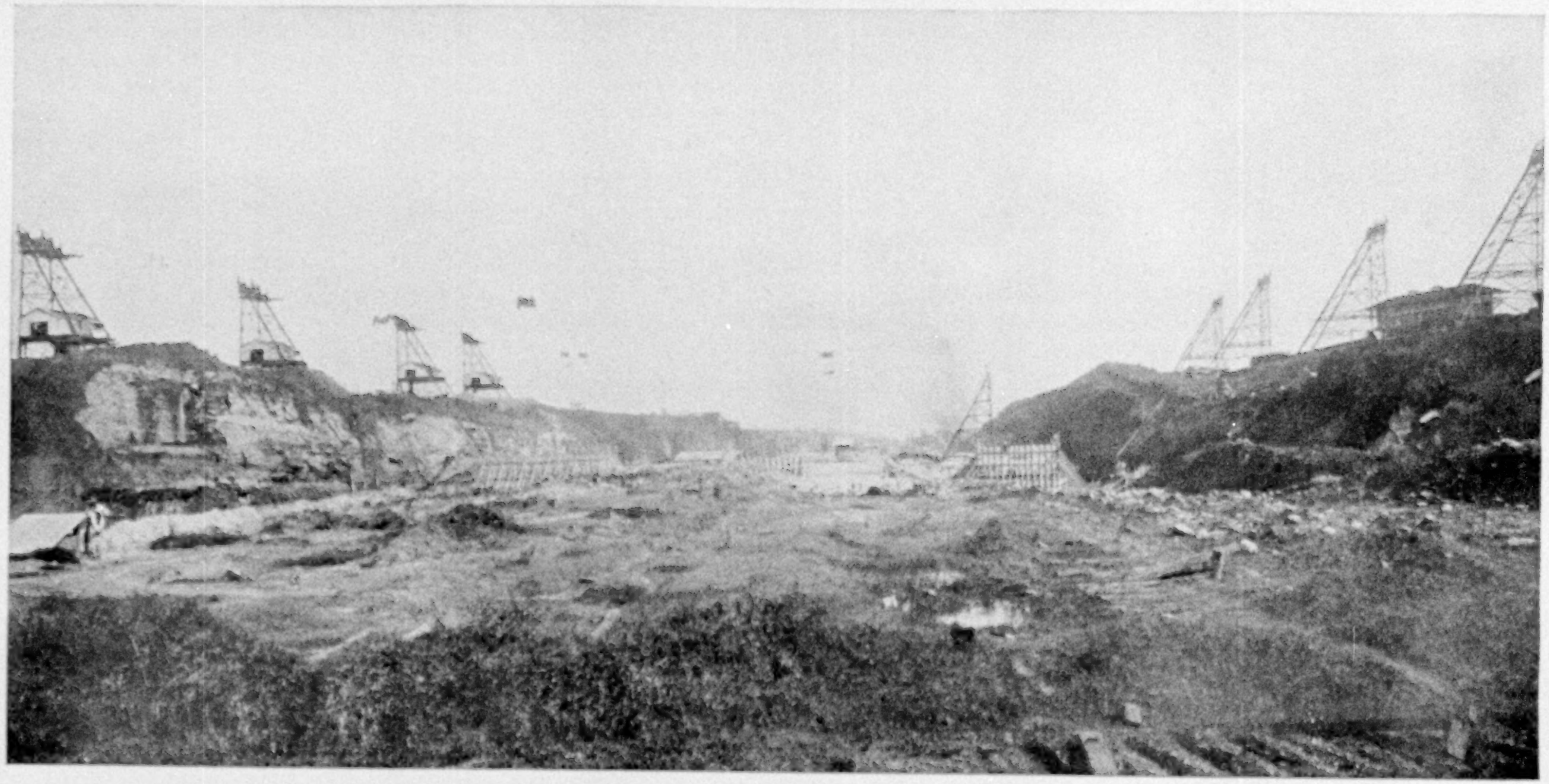


To handle the millions of tons of stone, sand, and cement required for building the locks, ingenious machinery has been installed which automatically selects the right proportions of stone, sand, and cement and mixes the material. The piles in the foreground in the above picture are sand; the darker piles on the further side of the railway track are stone. Grab-buckets shoot down from the arms of the crane, bite into the piles, shoot back to the crane, and feed their loads into the mixer, where cement has been already delivered in bags or barrels.



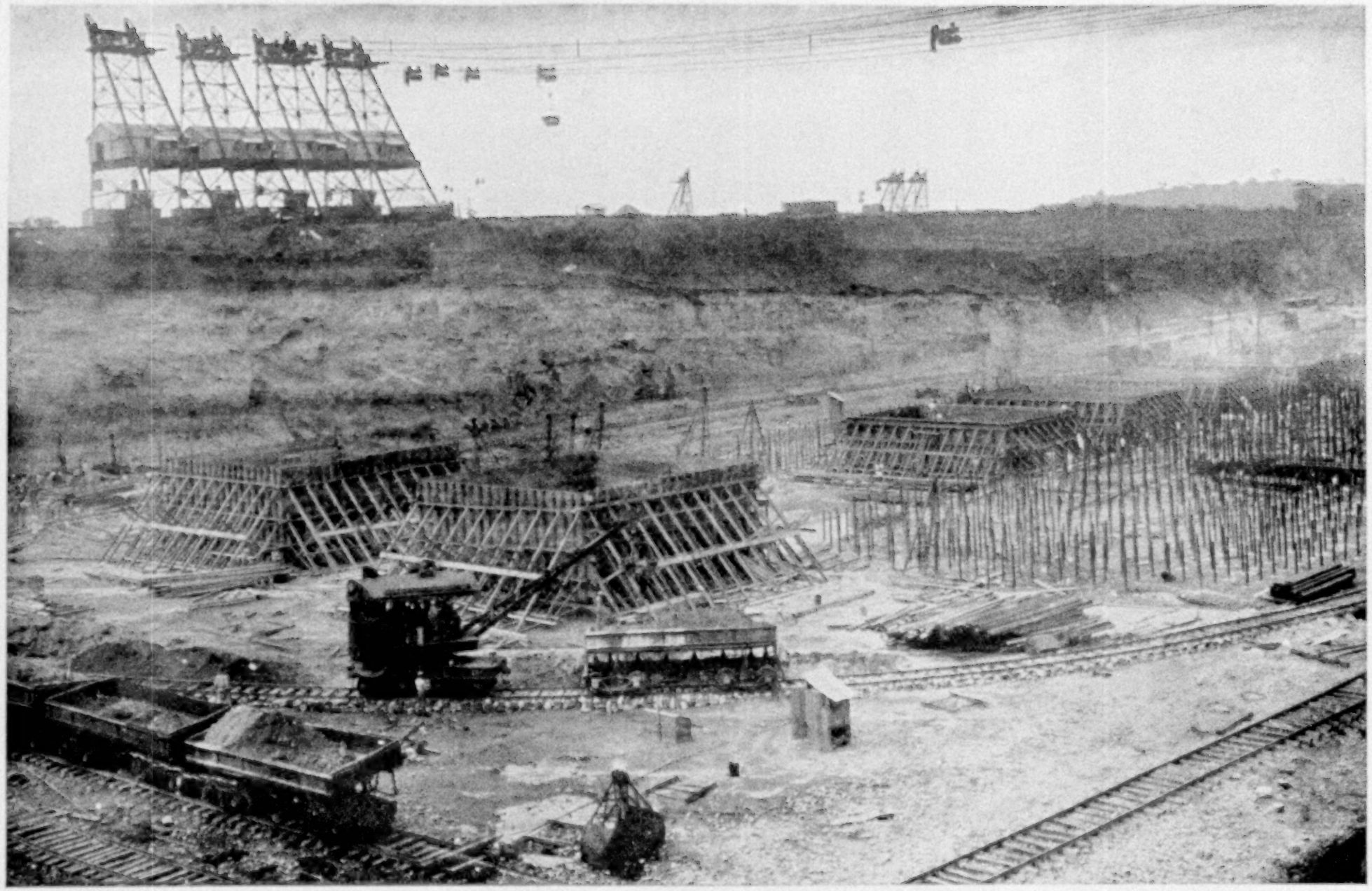
ONE OF THE AUTOMATIC CONCRETE MIXERS LOADING CONCRETE IN BUCKETS

The government has contracted for 4,500,000 barrels of cement for the various locks, dams, and structures of the canal. If these barrels were placed in a single line touching each other they would reach from New York to Denver



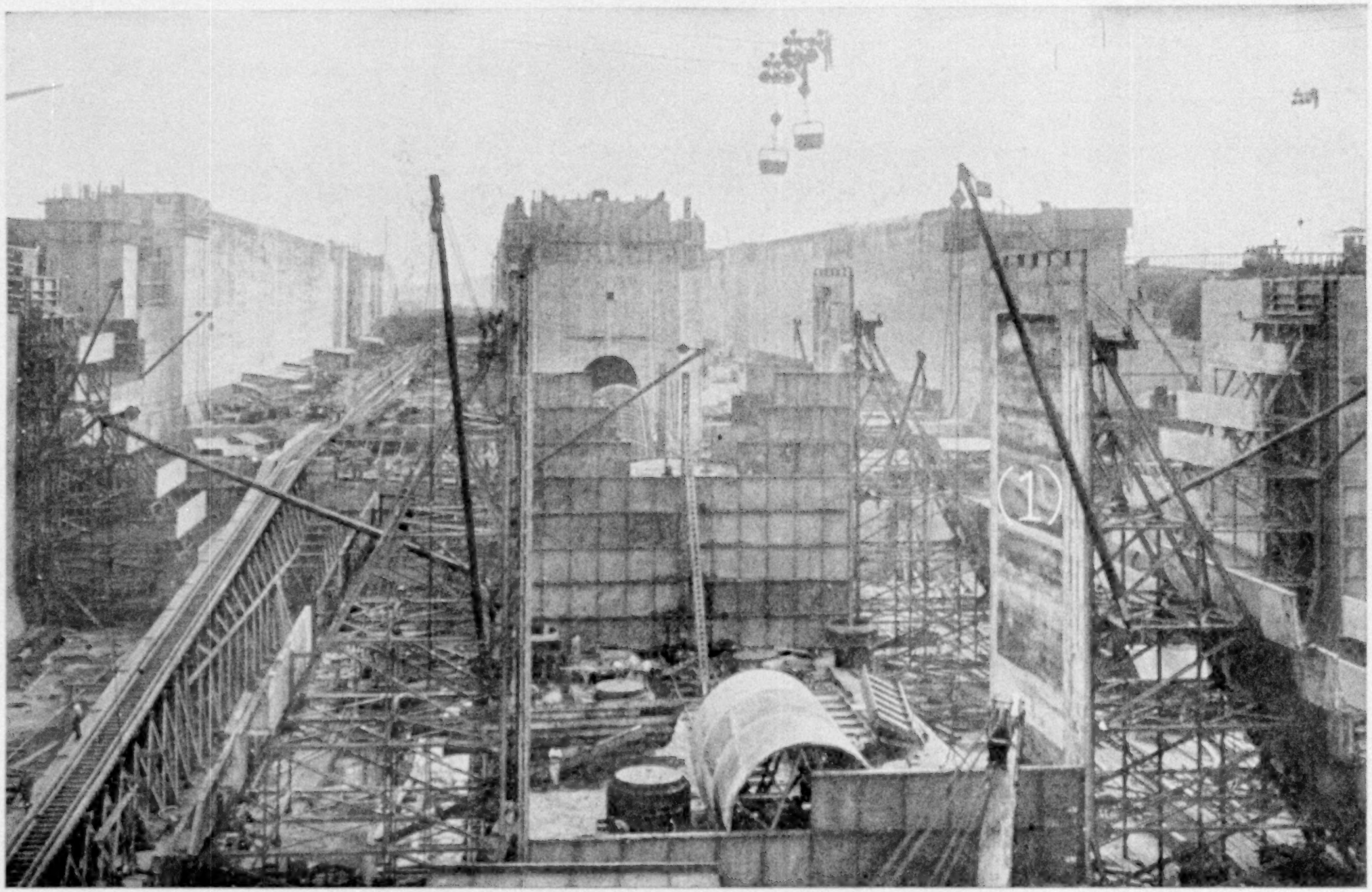
GENERAL VIEW OF UPPER LOCKS AND FOREBAY, GATUN, LOOKING NORTH, IN 1909

Four duplex cableways span the locks, with steel towers 85 feet high and 800 feet apart. They pick up from the delivery car the big buckets of concrete, send them out on the aerial trams, and lower them where required. One man operates a cableway, controlling all the movements by switches located on a platform on each head tower. In addition to delivering concrete in the locks, the cableways are used to lift material from the lock site and dump it by an aerial dumping device, to handle forms for the concrete work, and to handle the parts of the gates and the gate-operating machinery. The carrying cable is a locked steel wire 2¼ inches in diameter, its carrying capacity being considerably over 6 tons. Twenty trips an hour can be made on each cableway. The greatest lift is 170 feet. The towers are set on tracks on which they can be easily moved along the lock site as the work progresses.



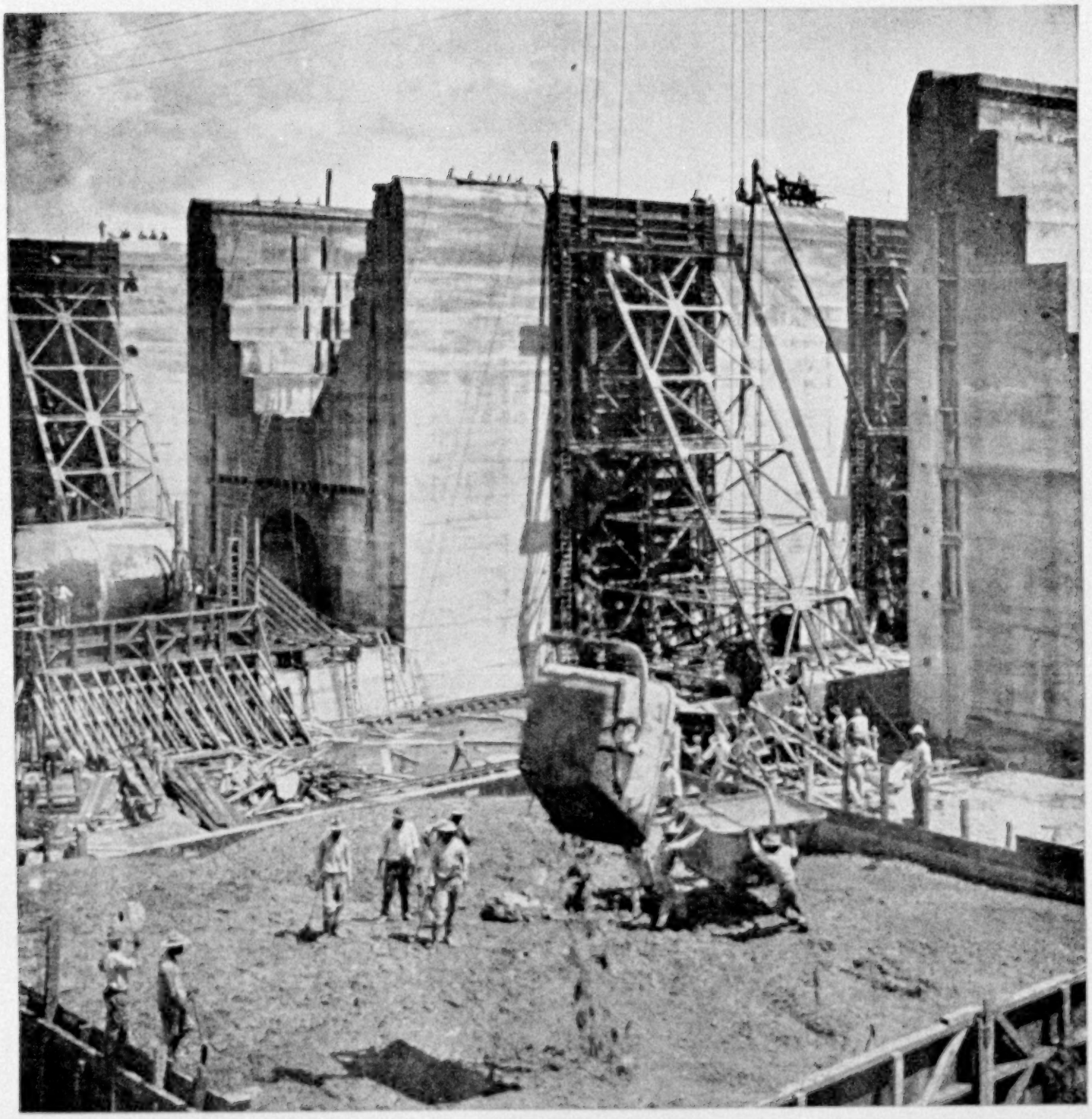
ANOTHER VIEW OF THE AERIAL CABLEWAYS USED AT THE GATUN LOCKS: LOOKING NORTH FROM EAST BANK, AUGUST 25, 1909

This illustration shows the early stages of the construction of these locks. The two "squares" on the left are timber forms in which concrete was laid in sections for the foundations. The uprights on the right are old French rails imbedded in the concrete to reinforce the floor. The floor of the Gatun locks varies in thickness from 13 to 20 feet of solid concrete reinforced with these rails.



BUCKETS OF CONCRETE READY TO DESCEND AND BE PLACED BY THE MEN WAITING BELOW

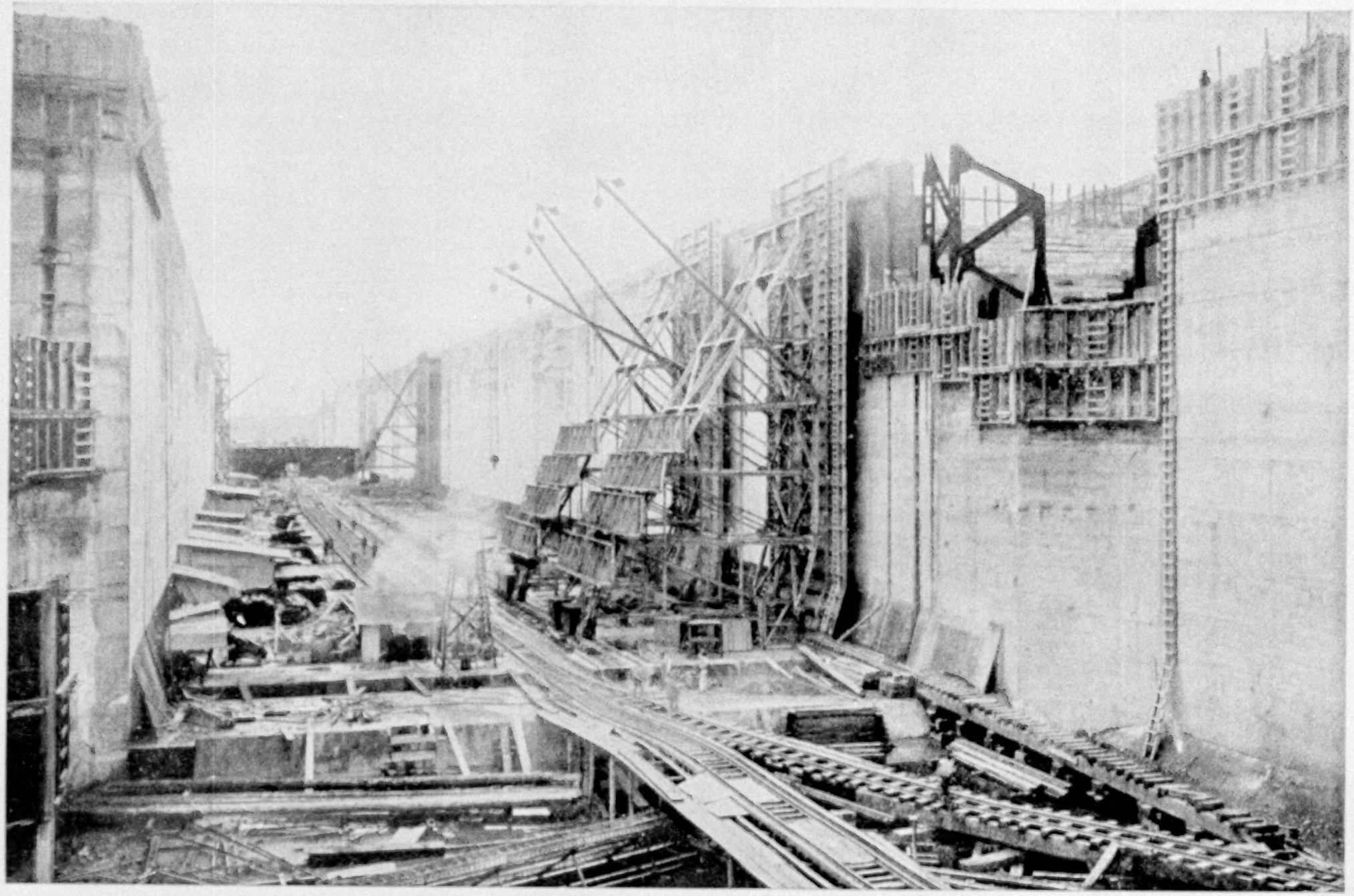
This view of the upper locks at Gatun (looking south from the middle lock) was taken December 30, 1910, and shows the walls of the twin upper locks practically completed. Note the steel forms (1) for the construction of the walls (see pages 200, 204, and 205)



RECEIVING THE CONCRETE

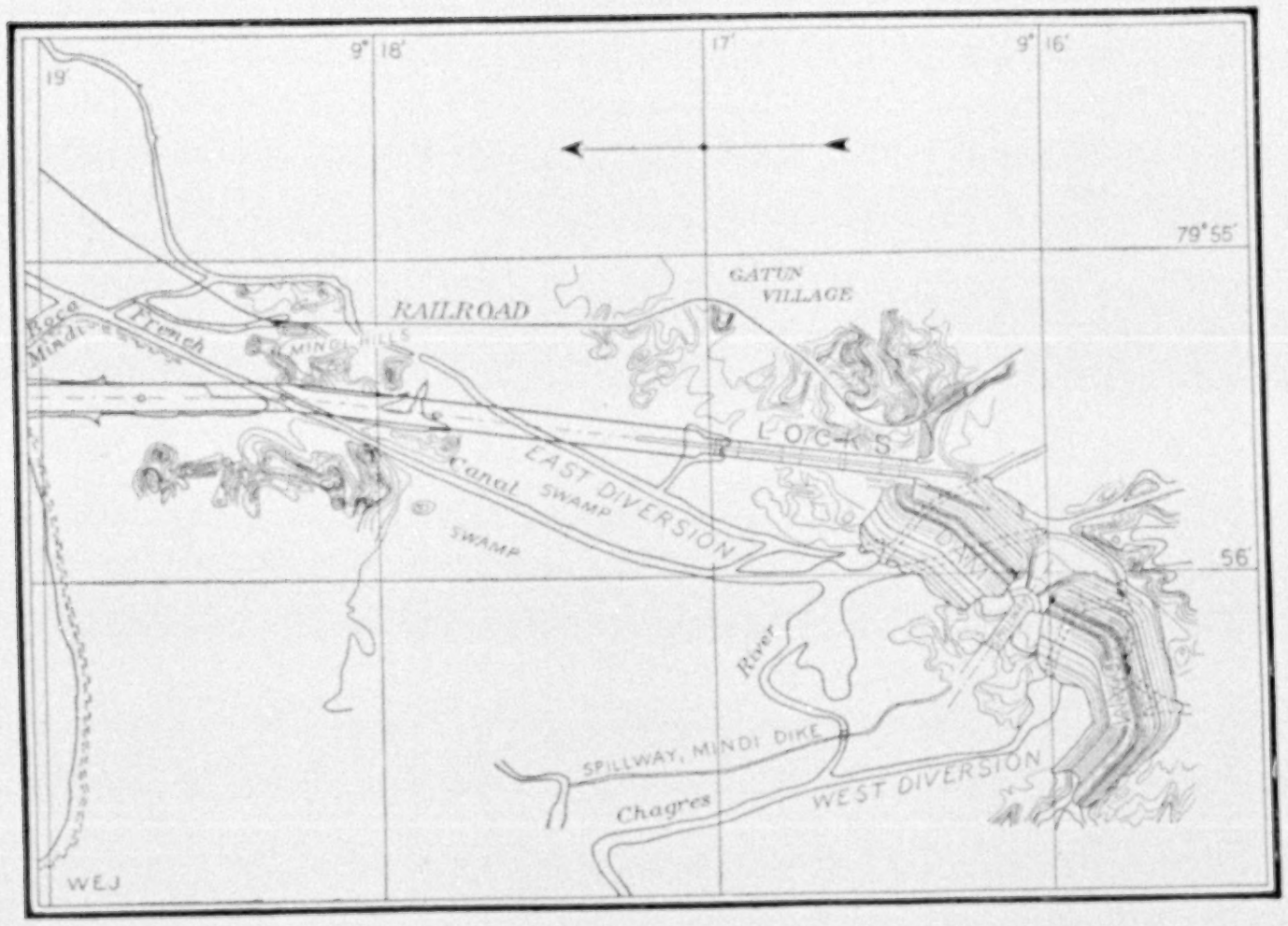
Note the men standing on top of the wall on the extreme left. The largest amount of concrete laid in any one month at Gatun is 89,401 cubic yards. The average cost of the concrete per yard in place for 1910 was $7.355, including plant charges and division expenses. To build the Gatun locks 2,250,000 barrels of cement will be required.

be noted that the maximum lift for these locks is about 65 feet. The excavation for the upper set of locks is complete and for the lower set it is about 70 per cent complete. It was not intended to lay any concrete until the plant at Pedro Miguel had finished the locks at that locality, but, as the work has advanced so much more rapidly than anticipated, and as the contractors are to complete the erection of the gates seven months earlier than expected, it became necessary to install auxiliary mixers and begin this part of the work earlier. There will be



THE EAST CHAMBER OF THE UPPER LOCKS AT GATUN, LOOKING SOUTH: DECEMBER 16, 1910

Note the steel towers for holding the face forms, which in this view are shown moved away from the wall preparatory to removal to a new location (see pages 198, 204, and 205). Each lock at Gatun is 110 feet wide and has a usable length of 1,000 feet



MAP OF GATUN DAM, SPILLWAY, AND LOCKS (SEE PAGES 177 AND 179)

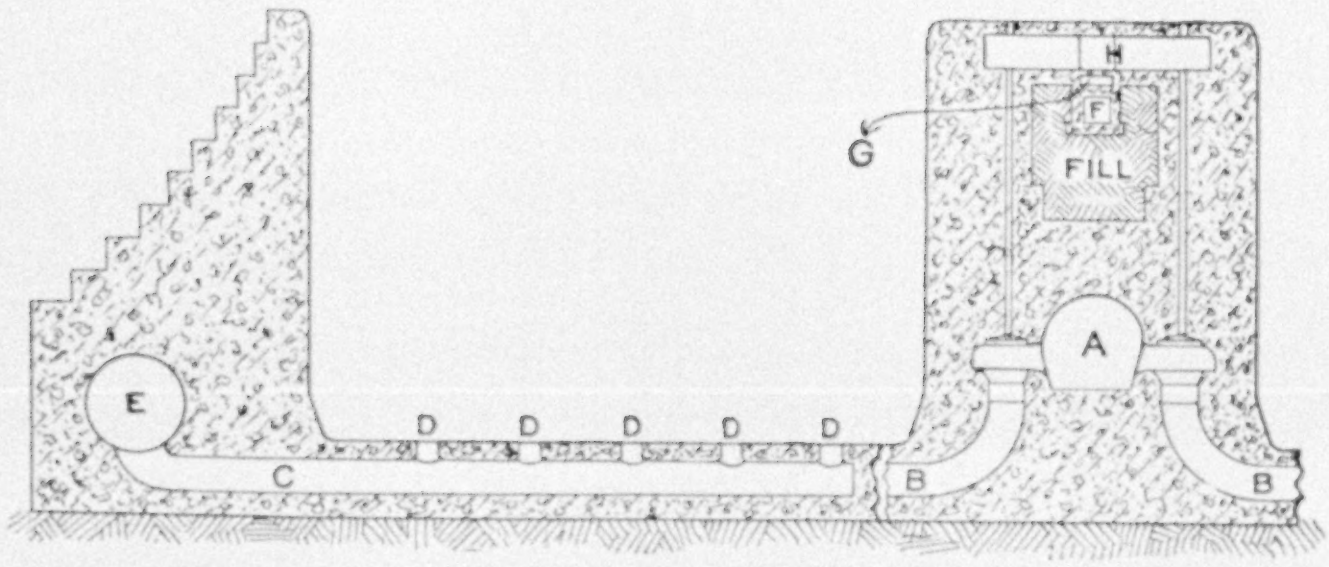
a total of 1,312,200 cubic yards of concrete to lay for these locks, of which 7 per cent is already done.

The Cocoli River, a tributary of the Rio Grande, crosses the site of the Miraflores locks from the west, and is such a formidable stream in times of heavy freshets that the protection of the locks against its floods during construction and after completion is necessary. A diversion channel through the hills to the west with a dam across the river valley would accomplish the desired end; but, as a dam at the head of and to the west of the locks is also necessary to impound the water for the pool above, the solution finally adopted was the construction of a dam extending from the head of the locks to Cocoli Hill, with a direction nearly parallel to the axis of the locks, by this arrangement the Cocoli River will discharge into the upper pool.

The dam is of earth, 2,300 feet long, top width 40 feet at reference 70, and the side slopes approximately 12:1. The average head to which the dam will be subjected is 30 feet, the maximum 40 feet. It is being constructed like the Gatun dam, and is 43 per cent complete. The east dam will be of concrete, approximately 500 feet long, provided with regulating works similar to and of the same dimensions as those at Gatun, the crest in this instance being at elevation 39, with seven openings, permitting a discharge of 7,500 cubic feet per second.

For a distance of one and one-half miles south from the Miraflores locks rock is found in the channel, to be excavated at an average elevation of minus 30. The estimated quantity to be removed is 1,503,260 cubic yards, which is covered by 8,158,133 cubic yards of alluvial material, averaging 38 feet in depth. It was not practicable to remove the earth and rock by dredging and subaqueous methods, as the requisite plant could not have been assembled to complete the work in the allotted time.

An hydraulic excavating plant was,



CROSS-SECTION OF LOCK CHAMBER AND WALLS, GATUN LOCKS

A. Culvert in center wall.
B. Connections between center and lateral culvert.
C. Lateral culvert.
D. Wells opening from lateral culverts into lock chamber.
E. Culvert in side wall.
F. Drainage gallery.
G. Gallery for electric wires.
H. Passageway for operators.

There will be three main culverts extending the full length of the locks, one in each of the side walls and one in the middle wall. The side-wall culverts are 22 feet in diameter from the intake at the south end of the upper locks to a point 320 feet north, where they are reduced to 18 feet, at which diameter they will continue to the end, a distance of about 3,500 feet. The culvert in the middle wall is 22 feet in diameter from its south end to a point 120 feet north, where it also will be reduced to 18 feet, at which diameter it will continue to the end, a distance of about 3,600 feet. Lateral culverts in the form of an ellipse will run in the floor from and at right angles to the main culverts at intervals of 32 and 36 feet, leading alternately from the side and middle culverts. Water will be delivered or collected by each lateral culvert through five openings or wells in the floor. Valves, which may be opened or closed either individually or all at one time, will be located at the intakes and outlets of the main culverts, and at the connections between the center culverts and the lateral culverts (see page 205). In the center space of the middle wall there will be a tunnel, divided into three stories or galleries. The lowest gallery is for drainage; the middle, for the wires that will carry the electric current to operate the gate and valve machinery, which will be installed in the center wall, and the top, a passageway for the operators.

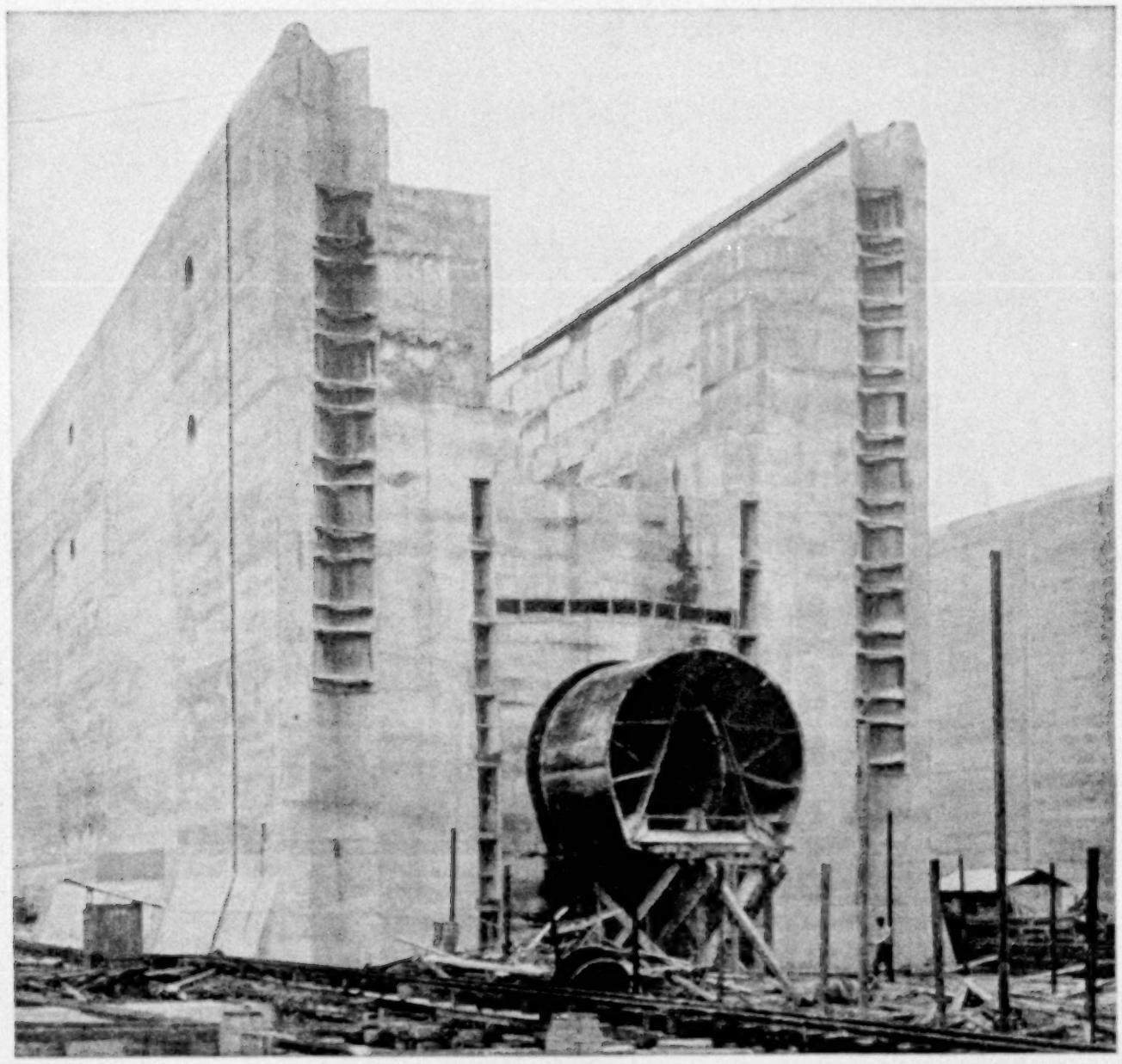
therefore, selected as being the cheapest and most expeditious method of handling the loam, especially because by this means 450 acres of swamp land adjacent to the canal could be reclaimed. Four hydraulic pumps force water through pipes, fitted with hydraulic giants or monitors, with a pressure of 130 pounds per square inch at the nozzles; these jets wash the loam to sumps, from which 18-inch centrifugal dredging pumps, mounted on reinforced concrete barges, pump the material to such places as may be desired.

Below the area to be excavated in this manner, the channel is secured by ordinary dredging operations. Rock encountered is blasted, the drilling being done by churn drills through the natural surface to the proper depth or, where submerged, by use of a drill scow. A Lobnitz rock breaker is also in use for preparing the rock for the dredges. The total amount of material to be excavated aggregates 35,000,000 cubic yards, of which 73.55 per cent is completed.

REBUILDING THE RAILROAD

The relocated Panama Railroad is being pushed forward so as to keep pace with canal construction work. From Colon to Mindi and from Corozal to Panama, the old line, relieved of some of its curvature, will be used, but the remainder must be rebuilt. From Mindi to Gatun, two miles, and from Paraiso to Corozal, four miles, the new line is completed and is being operated.

Just south of Miraflores the new road passes through a tunnel 800 feet long.



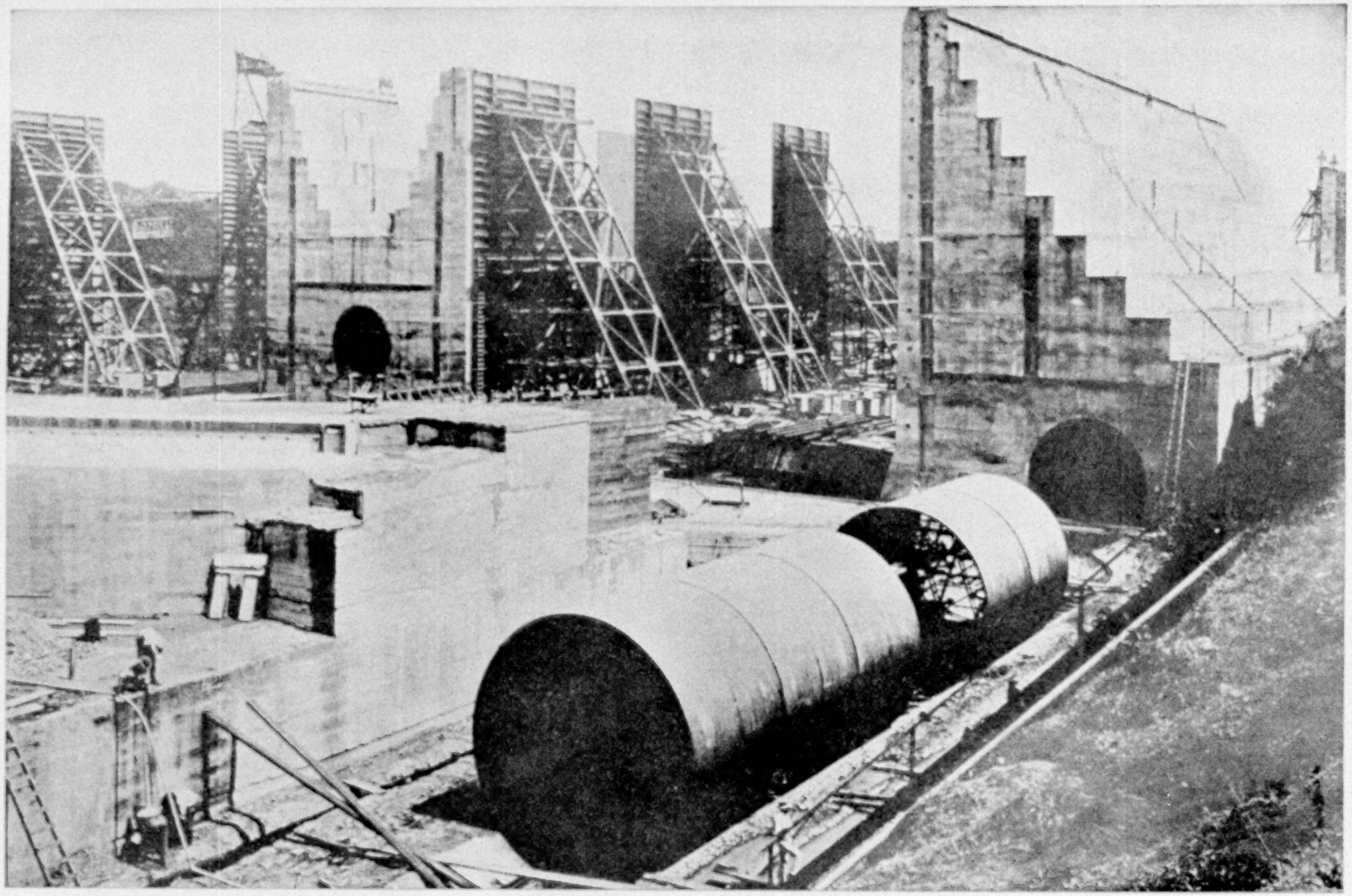
THE MIDDLE WALL OF THE GATUN LOCKS

The size of the structure can be appreciated by noting the man at the bottom. The great cylinder is the culvert to fill or empty the locks (see page 202)

The section from Frijoles to Gamboa, 9 miles, is complete to grade and has been turned over to the Central Division for use in wasting material. This includes a steel bridge across the Chagres nearly one-quarter of a mile long. From Gatun to Frijoles a temporary line was completed up to grade 60 in April, 1910, and maintained ready for operation at any time during the past wet season that the old line was flooded out.

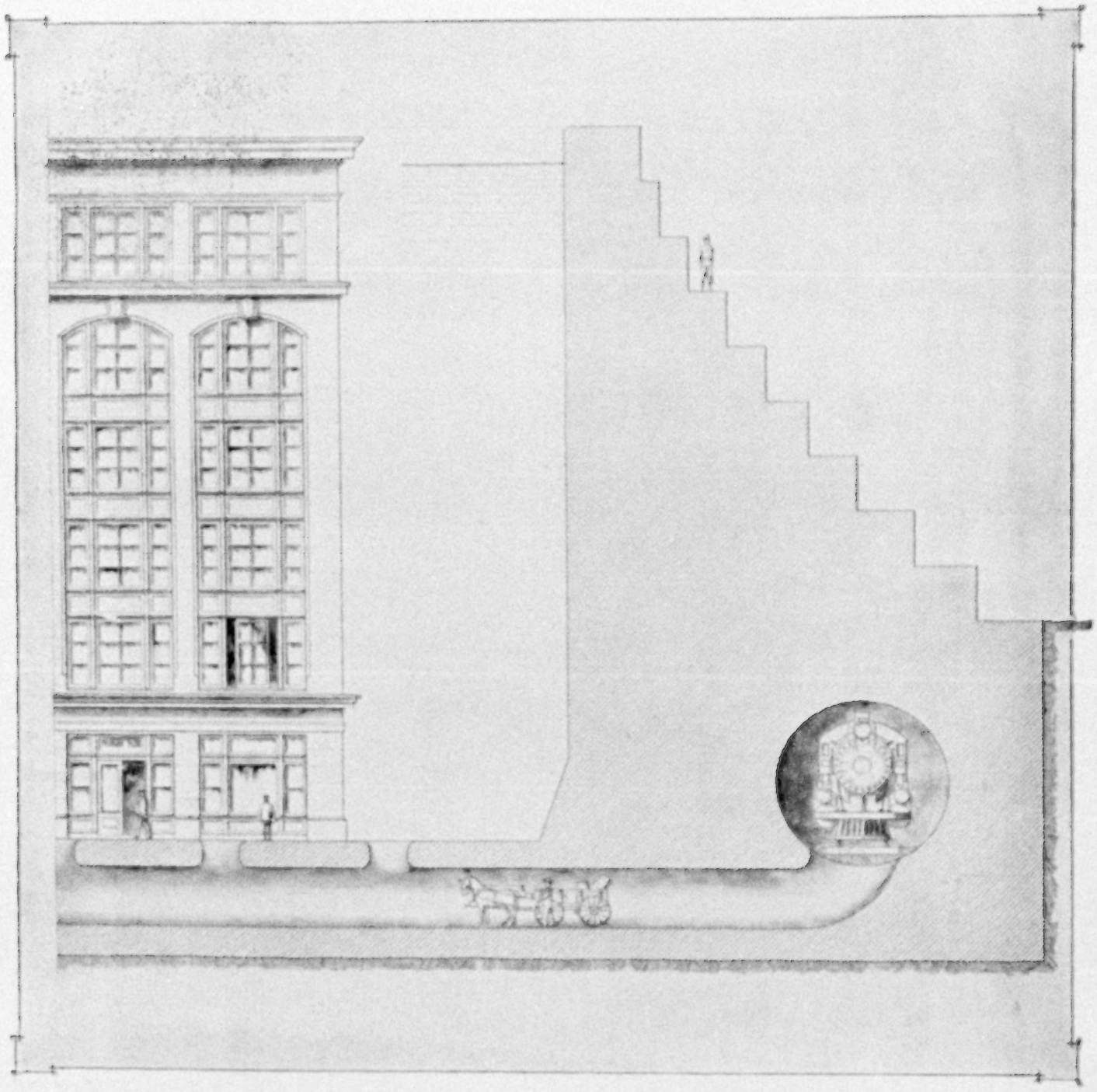
About 3,000,000 cubic yards are still required to complete the embankments of this section to elevation 95, and every effort is being made to finish the entire line to Gamboa, 31 miles, to full grade by January 1, 1912. On this date it is expected that work in the Gatun spillway will have progressed sufficiently to begin raising the lake to elevation 55.

Construction of the line from Gamboa to Paraiso, east of the cut, was started in January and will be pushed with a view to completion by January 1, 1912, if possible. As the greater part of the road passes through the lake, reinforced concrete culverts are provided to equalize the water on both sides of the embankments.



The great barrels are the steel collapsible forms for the culverts in the side wall. The steel towers in the distance hold the face forms (see page 198). Forms for the culverts are made of open-hearth boiler steel, are collapsible, are mounted on wheels to facilitate withdrawal, and are constructed to stand five years of continual use. For the main culverts in the side walls there are 21 forms in 12-foot lengths, each form weighing not less than 14,443 pounds. There are 12 forms for the culvert in the middle wall, each 12 feet long and weighing not less than 14,750 pounds. There are 100 forms for the lateral culverts, each 10 feet long and weighing not less than 2,170 pounds.

XUM

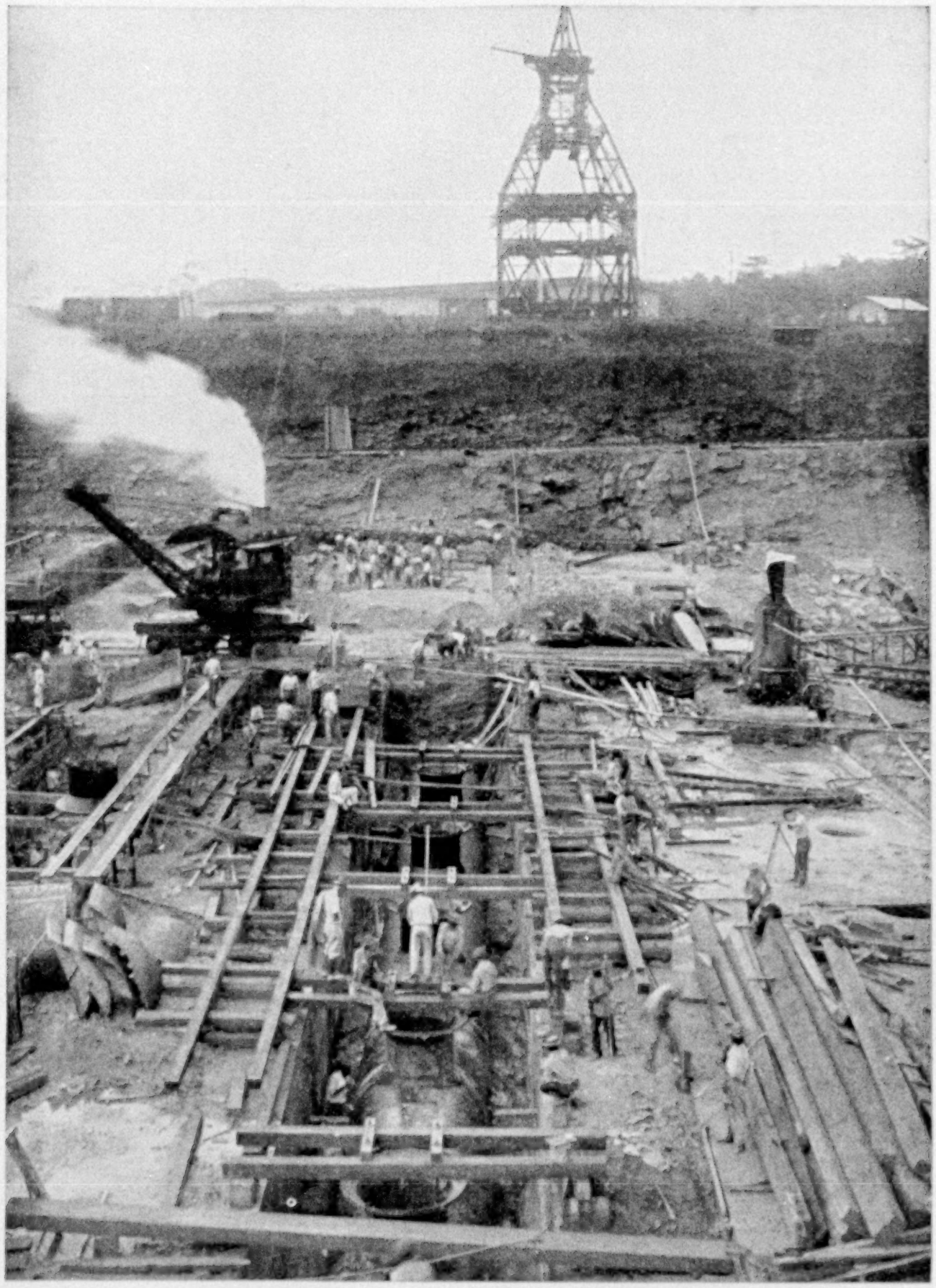


THE SIDE WALL OF ONE OF THE GATUN LOCKS COMPARED TO A SIX-STORY BUILDING

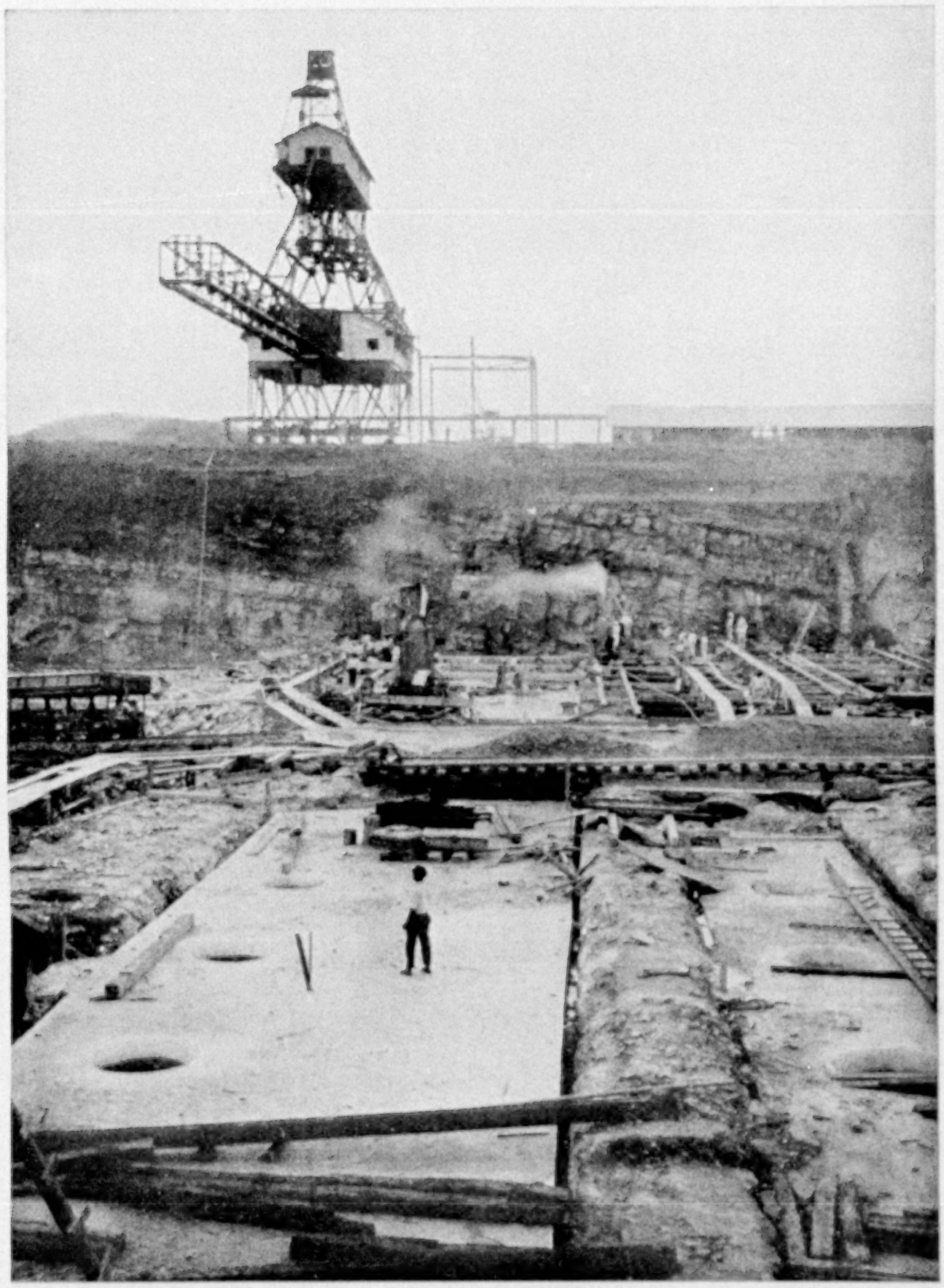
The size of the culverts may be appreciated from the engine and dray. The "steps" will be filled in with earth and stone and graded to the top. Face forms for the side and center walls (see preceding illustration) are of sheet steel carried on movable towers, also built of steel. Tracks are laid as near to the line of the walls as possible, and on these tracks the towers move up and down the lock chambers parallel with the walls (see page 200). Jacks fixed to the towers and bearing on the forms are used to align the forms and hold them in place. There are 12 of these towers, with forms 78 feet long from top to bottom, 36 feet wide, and 7½ inches thick (see page 198).

THE CANAL WILL BE COMPLETED ON TIME

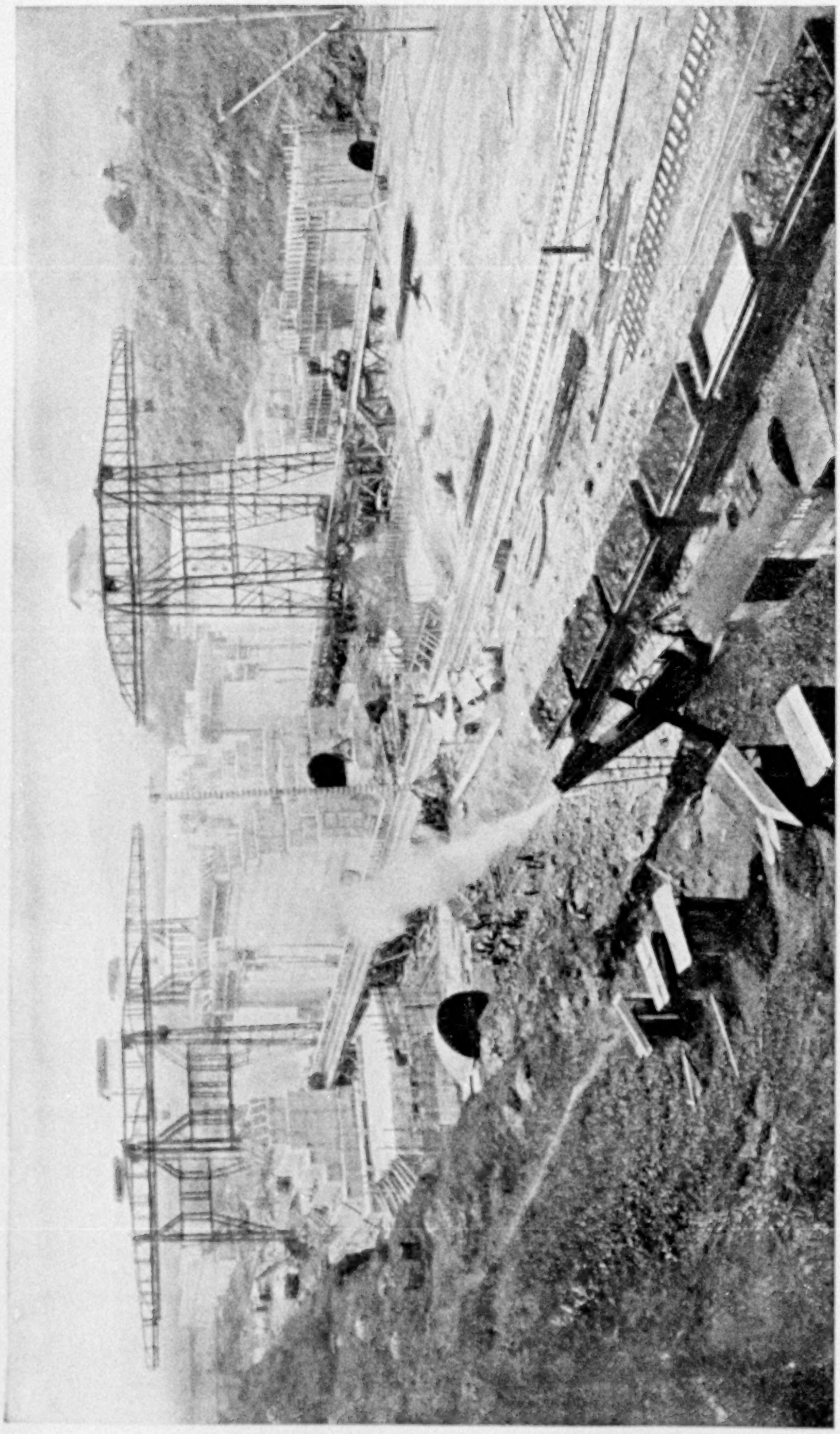
Generally speaking, employees are selected on account of their special fitness for the work in hand, and are then unhampered in their methods of securing definite results, thus bringing out to its fullest extent individual effort and brain power. As a consequence each man has a personal interest in the work and seems imbued with the idea that the success of the enterprise depends on him. The spirit of enthusiasm and of loyalty



PLACING THE FORMS FOR THE LATERAL CULVERT IN THE MIRAFLORES LOCK



ANOTHER VIEW OF THE FLOOR OF THE MIRAFLORES LOCK, SHOWING THE OPENINGS TO THE CULVERTS BY WHICH THE LOCK WILL BE FILLED AND EMPTIED



VIEW OF THE PEDRO MIGUEL LOCKS, LOOKING SOUTH FROM THE EAST BANK: AUGUST 30, 1910

The steep banks on either side make the arrangement of aerial cableways used at Gatun impracticable, and hence these chamber cranes are used. Each crane is mounted on four heavy freight-car trucks, which carry it along as the work progresses. All the machinery is in the house on top of the tower.

A VIEW OF THE PEDRO MIGUEL LOCKS (LOOKING NORTH FROM THE SOUTH END) TAKEN DURING A FLOOD: DECEMBER, 1910

The isthmus is not 50 miles wide where the canal cuts it, and yet the rainfall varies to an extraordinary degree in this short distance. At La Boca, on the Pacific, the average fall recorded for 12 years is 69 inches per year, while at Bohio the average for 13 years is 130 inches per year, and at Christobal, on the Atlantic, 128 inches per year for a period of 38 years. The months of January, February, and March are practically rainless. In the seven months from May to November, inclusive, 85 per cent of the rainfall occurs.

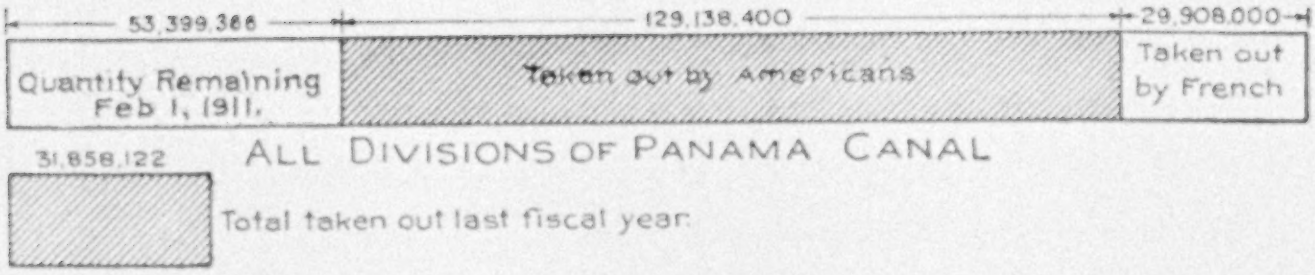


DIAGRAM TO SHOW PROPORTION OF EXCAVATION OF CANAL ALREADY COMPLETED

The quantity remaining to be excavated may, however, be considerably increased by slides into Culebra Cut (see pp. 167 and 173). The figures are cubic yards

among the canal workers strikes forcibly every one who visits the Isthmus, and convinces the doubting that the canal will be built.

The time required for completing the lock type of canal was estimated by the Board of 1905, which made its report in January, 1906, at 9 years, in accordance with which the work should be completed by January 1, 1915, and this is still retained as the date for the official opening. The expectation that the locks will be completed by June 1, 1913, is dependent on the gate contract and has already been noted, which leaves Culebra Cut as the doubtful factor.

THE SLIDES IN CULEBRA CUT ARE THE ONE DOUBTFUL FACTOR

Assuming that all the material will slide into the cut that was estimated in June last, so that all of it will have to be removed, it is estimated that this part of the cut will be finished by September1, 1913. It is well within possibility—indeed, it is probable—that other slides or breaks will develop, and it may be more economical to admit the water, thus getting the advantage of the back pressure, and remove the remainder by dredges, which will then be available and which can be passed through the locks when completed. This will be done if need be, but in any event there is nothing that can be foreseen at present which will postpone the date fixed for the official opening, with ample time to spare for tuning up the operating machinery and to organize and train a force for the operation and maintenance of the canal by January 1, 1915.

With concrete work in the locks coming to a close in the early part of 1912, steps must be taken to disband the present organization. The time has arrived for outlining an organization for the operation and maintenance of the canal. The tuning up of the machinery and the training of an organization will require the actual use of the canal. It is stated on reliable authority that at least 18 months will be required for shipping to adjust itself to the new conditions that will exist when the canal is ready for use. Such readjustment, however, will not be attempted until some definite announcement is made of the tolls that are to be charged and the basis for such tolls.

THE CANAL IS WORTH THE $375,000,000 INVESTED

Much has been said and predicted as to the commercial value of the canal to the United States. In this connection it must be remembered that the commercial shipping of this country never required the canal. The trip of the Oregon in 1898 settled the question of the advisability of constructing an Isthmian Canal, and had the canal been built at that time, thereby saving that trip around the Horn, there is no question that it would have been agreed generally that the canal, even at an expenditure of $375,000,000, was worth while.

In whatever light the Panama Canal is viewed, it will have paid for itself if in time of war or threatened war a concentration of the fleet is effected without that long, tedious, uncertain route followed by the Oregon.

It will practically double the efficiency of the fleet, and, notwithstanding the fact that we are a peaceful nation, our outlying possessions make the Panama Canal a military necessity, and it must be so recognized. From this point of view the debt should be charged to the account which necessitated its construction, and whatever revenues are derived from other sources are so much to the good. The traffic that will utilize the canal depends upon the tolls that will be charged, and the President has asked the Congress for legislation which will enable the establishment of rates.

There is another policy which if adopted will have a material bearing on the revenues of the enterprise. Through the Panama Railroad a large expenditure of money has been made for providing the present working forces with supplies of all kinds. Though the railroad has been reimbursed for this plant through fixed charges on sales, it should not be abandoned, but utilized for furnishing shipping with its needed supplies. Suitable coaling plants should be erected for the sale of coal to vessels touching at or passing through the canal. In addition, since oil is now used on a number of ships plying in the Pacific, such fuel should also be on hand for sale by the canal authorities.

The extensive machine shops now located at Gorgona must be moved before the completion of the canal, and they should be established in connection with a dry dock that will be needed for commercial purposes, and utilized as a revenue producer for the canal. This policy also needs congressional action.

With properly regulated tolls, and with facilities for fully equipping, supplying, and repairing ships, the Panama route would offer many advantages and bring to it a sufficiently remunerative return to pay not only the operating expenses, but to gradually absorb the debt which the United States has incurred by its construction.

THE NATIONAL GEOGRAPHIC SOCIETY

THE speeches delivered before the National Geographic Society on the occasion of the annual banquet, Saturday evening, January 14, will be printed in full in the next number of the Magazine.

At the annual meeting of the Society, January 13, the eight members of the Board of Managers whose terms expired at the meeting were unanimously re-elected for the ensuing three years, viz., Alexander Graham Bell, Henry Gannett, J. Howard Gore, A. W. Greely, Gilbert H. Grosvenor, George Otis Smith, O. H. Tittmann, and John M. Wilson.

At a regular meeting of the Board of Managers, January 18, Mr. Henry Gannett was re-elected President; Mr. O. H. Tittmann, Vice-President; Mr. O. P. Austin, Secretary, and Mr. John Joy Edson, Treasurer, for the ensuing year. The reports of the Secretary and Treasurer for the year 1910 are printed below.

REPORT OF SECRETARY O. P. AUSTIN FOR THE YEAR ENDING DECEMBER 31, 1910

The year 1910 shows a large increase in the membership of the National Geographic Society and a general improvement in its condition and work.

The number of members December 1, 1909, was 53,333; the number added upon their own application during January 1-December 31, 1910, was 23,398; the losses by death, by resignation, and by non-payment of dues was 2,703, making the total membership on December 31, 1910, 74,018. Fifty-one new life members were elected during the year, making the total life membership 399.

The membership is distributed throughout all the States and Territories of the Union, and includes about 2,358 in the District of Columbia, and between 700 and 800 in the Philippines, Hawaii, Porto Rico, and Alaska. The membership in foreign countries is 2,404, and

Photo by P. G. Gates, of Pasadena, California

NAVAHO WOMAN AND BABY

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represents fifty different countries and colonies of the world, including all the European countries, Egypt, India, China, Japan, Australia, New Zealand, the various Central and South American countries, and several of the West Indian islands. The membership in Canada is 863; in Mexico, 450; in Cuba, 116; in Panama, 183; in Europe, 652, and in Central and South America, 129.

A gold medal was presented March 26, 1910, to Sir Ernest H. Shackleton for his explorations in the far south, the presentation being made on behalf of the Society by the President of the United States, William H. Taft. On November 18 ex-President Roosevelt addressed the Society on his recent expedition to Africa.

Honorable William H. Taft was elected an honorary member of the Society during the year in recognition of his active interest in the promotion of geographic science. The Society now has five honorary members, as follows: William H. Taft, Theodore Roosevelt, Robert E. Peary, George Dewey, and Frithjof Nansen.

REPORT OF TREASURER JOHN JOY EDSON FOR THE YEAR ENDING DEC. 31, 1910

RECEIPTS:		
Cash balance, as shown by statement of December 31, 1909		$10,614.55
Dues		120,442.16
Life members		2,550.00
Magazine—subscriptions and sales		11,504.93
Lectures		7,324.55
Advertising		15,403.28
Interest on investments and on bank deposit		1,826.77
Publications		8,567.62
Notes paid		12,000.00
Sundry		1,244.12
		$191,477.98
DISBURSEMENTS:		
Salaries and services	$24,312.27	
Magazine—paper, printing, articles, etc.	70,166.04	
Magazine—pound rate postage	4,700.00	
Postage	8,018.59	
Printing and stationery	10,999.25	
Lectures	7,215.73	
Hubbard Memorial Hall—lights, heat, telephone, furniture, etc.	1,053.03	
Publications	867.89	
Research Committee (Alaskan Expedition)	5,141.08	
Advertising commissions	711.17	
Taxes, all of 1910	298.17	
Medals	675.00	
Remodeling and repairs to No. 1152 16th street N. W.	943.42	
Purchase of lots 46 and 47, square 183, 57 feet on 16th Street N. W., adjoining present property of Society	32,021.22	
Sundry	2,164.97	
Cash on deposit in the Washington Loan and Trust Co.	22,190.15	
		$191,477.98

ASSETS DECEMBER 31, 1910

Notes, secured by first deeds of trust on real estate	$18,500.00
Publications on hand, at cost	3,500.00
Real estate:	
Lot 45, square 183, purchase price	11,338.95
Lot 46, square 183, purchase price	16,145.22
Lot 47, square 183, purchase price	15,876.00
Cash in the Washington Loan and Trust Co.	22,190.15
Assets December 31, 1910	$87,550.32
Assets December 31, 1909	59,453.50
Gain in assets, 1910	$28,096.82

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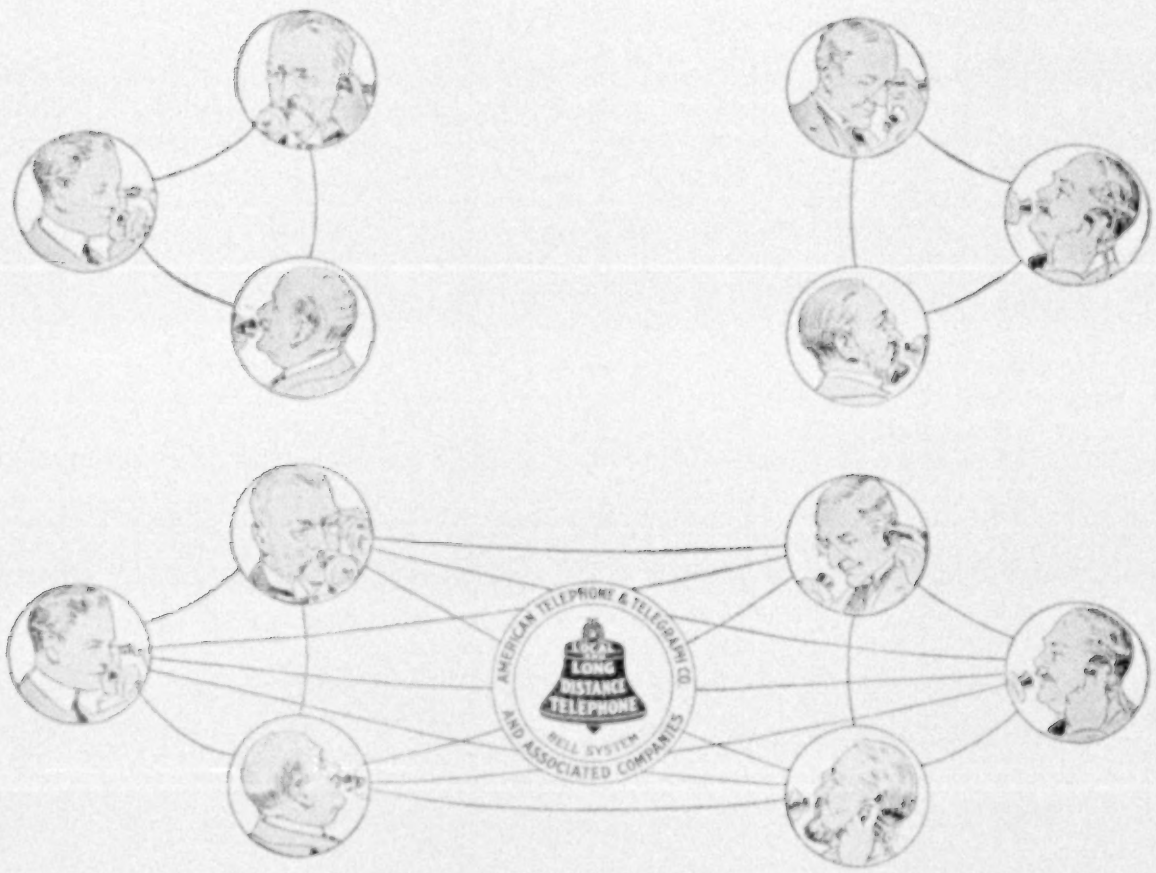

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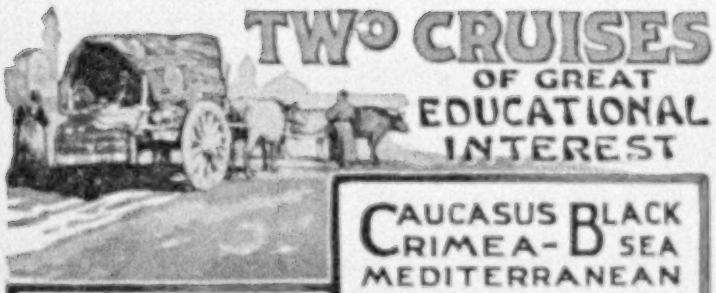

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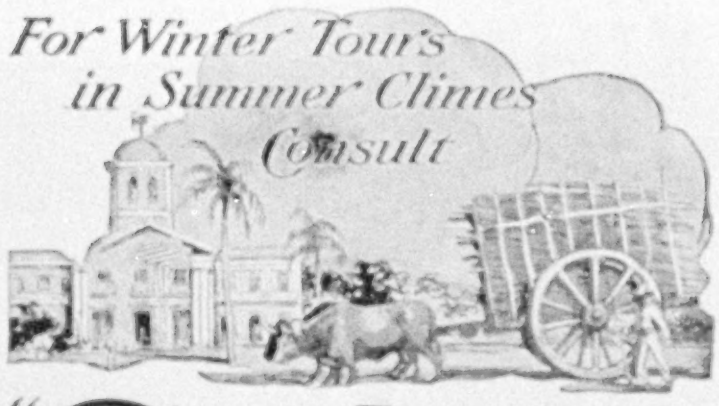

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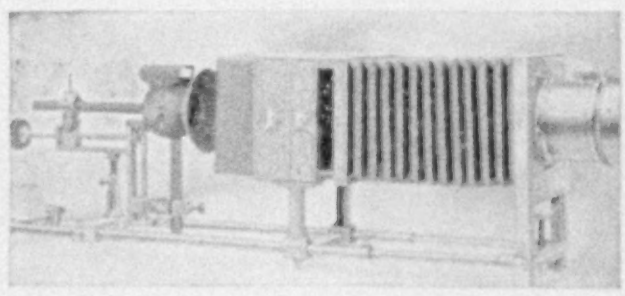

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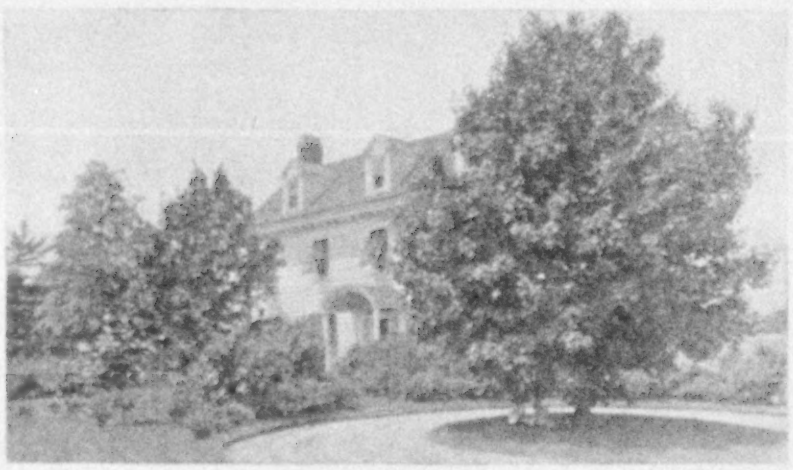

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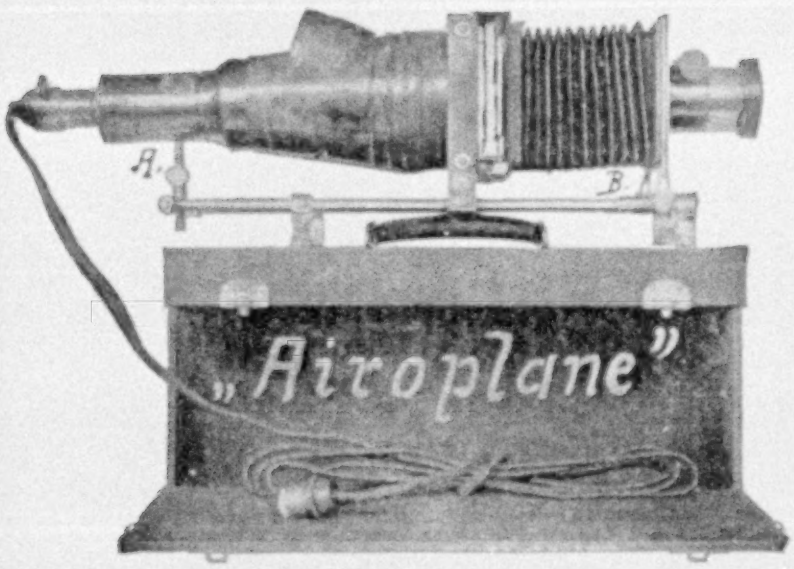

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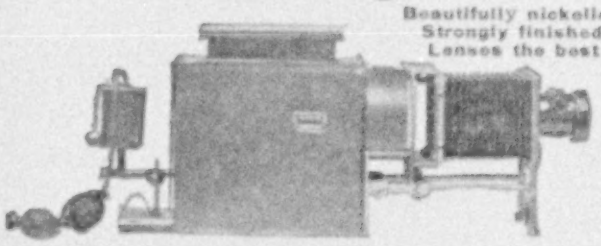

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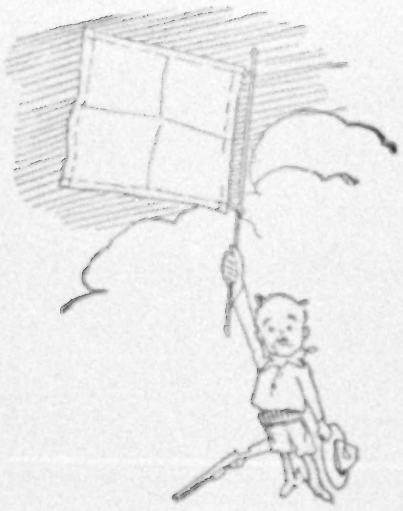

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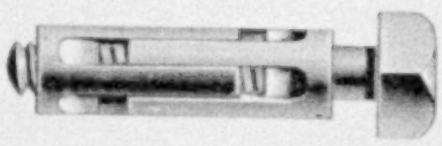

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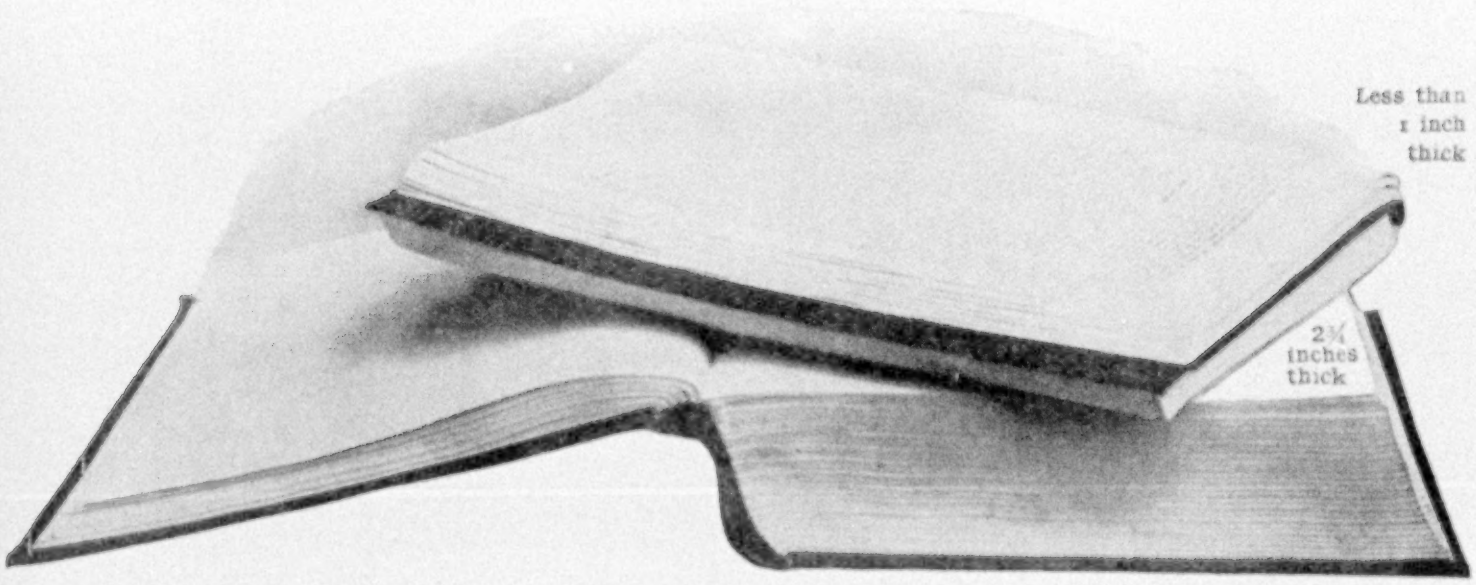

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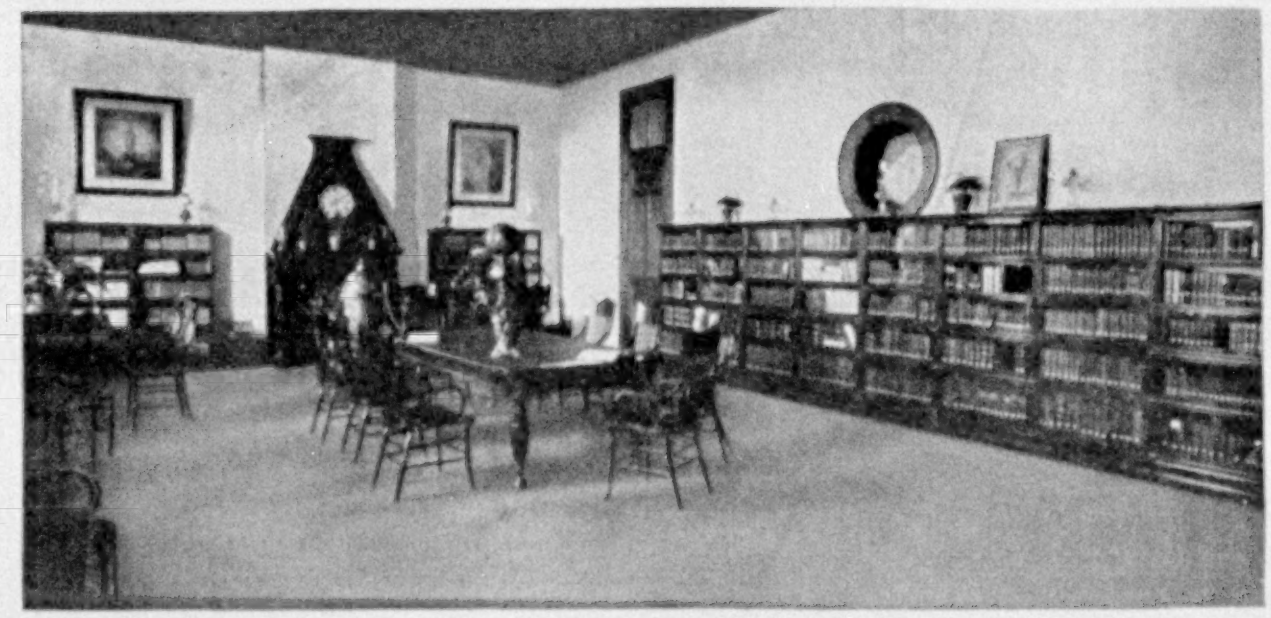

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